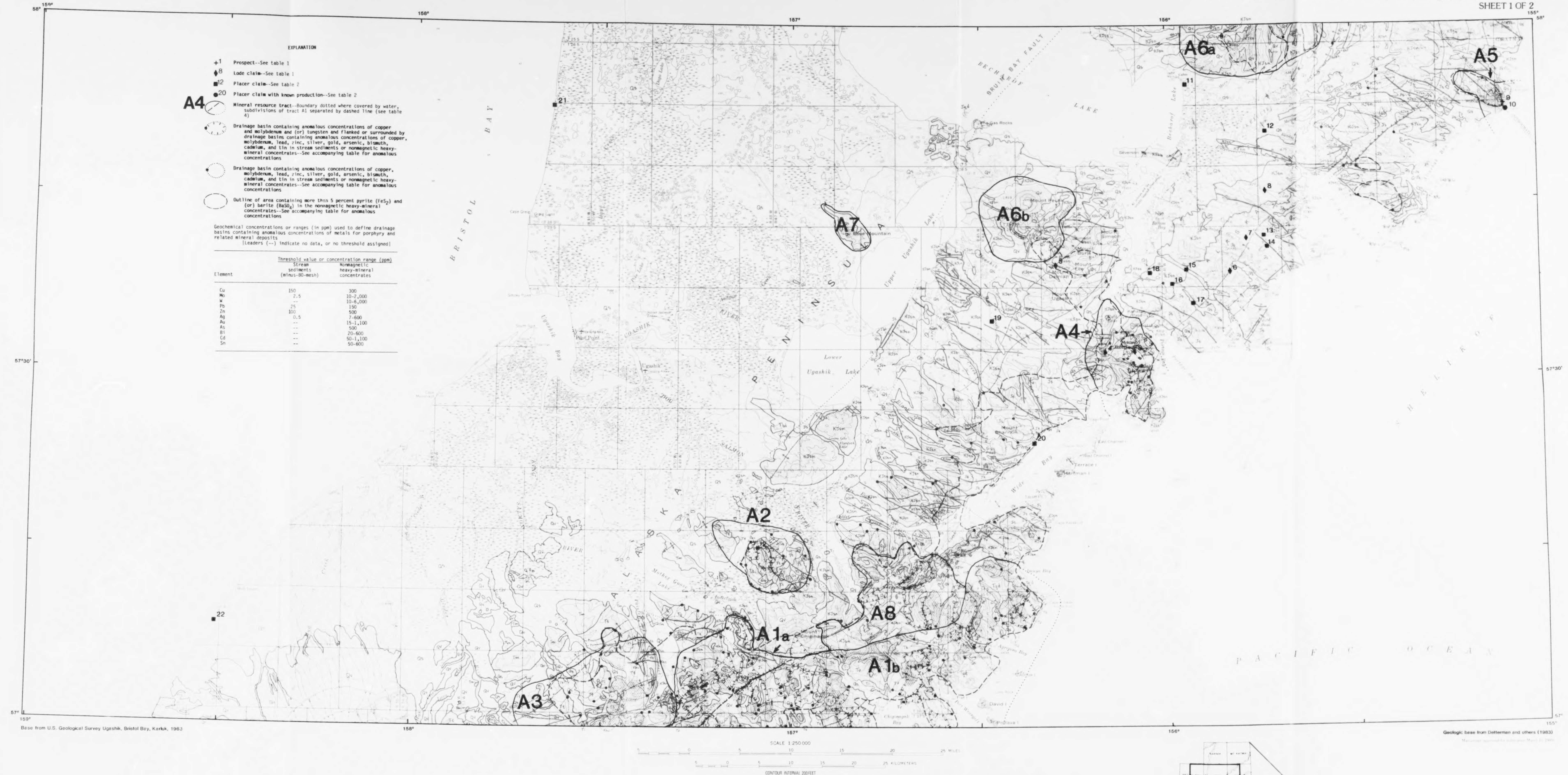
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF-1539I
FOLIO OF UGASHIK, BRISTOL BAY, AND WESTERN KARLUK QUADRANGLES, ALASKA
SHEET 1 OF 2



Base from U.S. Geological Survey Ugashik, Bristol Bay, Karluk, 1963

Geologic base from Detterman and others (1983)

EXPLANATION

+1 Prospect--See table 1

◆8 Lode claim--See table 1

■12 Placer claim--See table 2

●20 Placer claim with known production--See table 2

A4 Mineral resource tract--Boundary dotted where covered by water, subdivisions of tract A1 separated by dashed line (see table 4)

Drainage basin containing anomalous concentrations of copper and molybdenum and (or) tungsten and flanked or surrounded by drainage basins containing anomalous concentrations of copper, molybdenum, lead, zinc, silver, gold, arsenic, bismuth, cadmium, and tin in stream sediments or nonmagnetic heavy-mineral concentrates--See accompanying table for anomalous concentrations

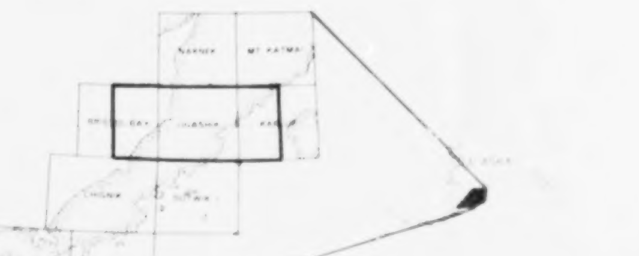
Drainage basin containing anomalous concentrations of copper, molybdenum, lead, zinc, silver, gold, arsenic, bismuth, cadmium, and tin in stream sediments or nonmagnetic heavy-mineral concentrates--See accompanying table for anomalous concentrations

Outline of area containing more than 5 percent pyrite (FeS_2) and (or) barite ($BaSO_4$) in the nonmagnetic heavy-mineral concentrates--See accompanying table for anomalous concentrations

Geochemical concentrations or ranges (in ppm) used to define drainage basins containing anomalous concentrations of metals for porphyry and related mineral deposits

[Leaders (--) indicate no data, or no threshold assigned]

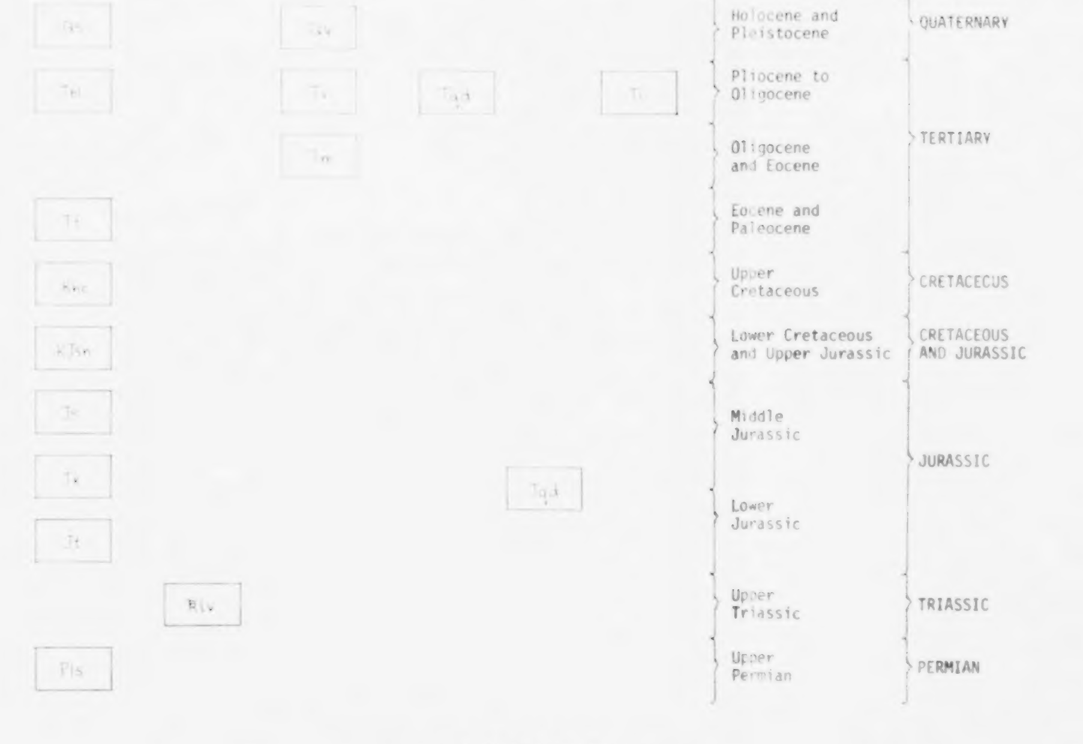
Element	Threshold value or concentration range (ppm) Stream sediments (minus-80-mesh)	Nonmagnetic heavy-mineral concentrates
Cu	150	300
Mo	2.5	10-2,000
W	--	10-6,000
Pb	25	150
Zn	100	500
Ag	0.5	7-600
Au	--	15-1,100
As	--	500
Bi	--	20-600
Cd	--	50-1,100
Sn	--	50-600



Map Area

MAP A.-METALLIC MINERAL RESOURCES

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS AND SEDIMENTARY ROCKS

Qs	SURFICIAL DEPOSITS (HOLOCENE AND PLEISTOCENE) - Unconsolidated alluvium, alluvial fans, and glacial, marine, lake, swamp, eolian, and landslide deposits; mainly silt, sand, gravel, pumice, and rock fragments
Tbl	BEAR LAKE FORMATION (MIOCENE) - Sandstone, siltstone, shale, minor coal, and conglomerate; nonmarine
Tt	TOLSTOI FORMATION (EOCENE AND PALEOCENE) - Sandstone, conglomerate, siltstone, shale, coal, and tuff; dominantly volcaniclastic and nonmarine
Khc	HOODOO AND CHIGNIK FORMATIONS, UNDIVIDED (UPPER CRETACEOUS) - Hoodoo Formation: dark rhythmically-bedded siltstone and shale, minor thin sandstone; deep-water marine. Chignik Formation: sandstone, conglomerate, siltstone, and shale; mainly shallow marine
KJsn	STANIUKOVICH AND NAKNEK FORMATIONS, UNDIVIDED (LOWER CRETACEOUS AND UPPER JURASSIC) - Staniukovich Formation of Late Jurassic and Early Cretaceous age: thin-bedded feldspathic sandstone, commonly laumontitic; minor siltstone and shale. Naknek Formation of Late Jurassic age: thin-bedded sandstone, siltstone, and dark shale with limestone concretions in upper part. Massive arkosic sandstone and conglomerate in lower part; abundant granitic- and metamorphic-rock clasts in conglomerate. Upper part marine; lower part nonmarine fluvial
Js	SHELIKOF FORMATION (MIDDLE JURASSIC) - Dark siltstone and shale with limestone concretions, sandstone, and conglomerate; nonmarine to near-shore marine, and deep-water turbidite
Jk	KIALAGVIK FORMATION (MIDDLE AND LOWER JURASSIC) - Sandstone, siltstone, mudstone, and shale; mainly shallow water marine
Jt	TALKEETNA FORMATION (LOWER JURASSIC) - Tuffaceous sandstone, siltstone, and limestone; minor bedded tuff
Pls	LIMESTONE (UPPER PERMIAN) - Light-gray massive crystalline limestone

SEDIMENTARY AND VOLCANIC ROCKS

Ɍlv	LIMESTONE AND VOLCANIC ROCKS (UPPER TRIASSIC) - Light- to dark-gray thin-bedded to massive limestone, limestone conglomerate, and basalt

VOLCANIC ROCKS

Qv	VOLCANIC ROCKS (HOLOCENE AND PLEISTOCENE) - Block and ash flows, debris flows, volcanic mud flows, cinder cones, and andesitic and dacitic lava flows; includes minor hypabyssal rocks
Tv	VOLCANIC ROCKS (PLIOCENE TO OLIGOCENE) - Basalt, andesite, and dacite lava flows, volcanic breccia, and rubble flows; locally includes hypabyssal rocks
Tm	MESHIK FORMATION (OLIGOCENE AND EOCENE) - Basalt flows, volcanic rubble flows, and lahars; locally minor volcanogenic sedimentary rocks

INTRUSIVE ROCKS

Tqd	QUARTZ DIORITE (PLIOCENE TO OLIGOCENE) - Agripina Bay pluton; hornblende-biotite and pyroxene-biotite quartz diorite; medium to coarse grained
Ti	INTRUSIVE ROCKS (PLIOCENE TO OLIGOCENE) - Diorite, quartz diorite, hypabyssal andesite and dacite
Jqd	QUARTZ DIORITE (MIDDLE AND LOWER JURASSIC) - Medium to coarse grained, hornblende and biotite bearing; part of the Alaska-Aleutian Range batholith

CONTACT--Dotted where concealed

The Alaska-Aleutian Range batholith of Jurassic, Cretaceous, and early Tertiary age (Reed and Lanphere, 1969, 1973) only crops out on a small island in Becharof Lake. This outcrop has been dated using K-Ar determinations on hornblende and biotite separates at 172 and 176 Ma, respectively (Reed and Lanphere, 1969). The Jurassic plutonic rocks of the batholith were emplaced to form the core of the Alaska Peninsula and are, in part, contemporaneous with the Lower Jurassic Talkeetna Formation, which consists of volcanic rocks and tuffaceous sandstone, and the Lower and Middle Jurassic Kialagvik Formation which consists of shallow-water marine sandstone and shale. Later, the Middle Jurassic Shelikof Formation, composed of volcanically derived sandstone, conglomerate, siltstone, shale, and minor deep-water turbidite, was deposited. Rocks of the Shelikof Formation are exposed along the Pacific Coast of the study area and the Kialagvik Formation is exposed at Wide Bay on the axis of the anticline centered in Wide Bay and at Puale Bay (Allaway and Miller, 1984). During Late Jurassic time, the Staniukovich and Naknek Formations, which were derived from the erosion of the Alaska-Aleutian Range batholith, were deposited. The lower conglomeratic part of the Naknek Formation was deposited in a nonmarine fluvial environment, whereas the upper sandstone and shale units, containing limestone concretions, represent a marine environment. Detterman, Case, and others (1987) suggested that the rocks mapped as the Staniukovich Formation in the study area represent essentially continuous sedimentation and may be best considered to be a member of the Naknek Formation. Throughout the discussion in this paper, we will use the term "Naknek" Formation to include these rocks. Overlying these rocks is the Chignik Formation of Late Cretaceous age which was deposited in a cyclical fluvial to nearshore marine sedimentary environment (Detterman, 1978). The Cretaceous Hoodoo Formation interfingers with and overlies the Chignik Formation and is a turbidite indicating a deeper-water environment.

The Meshik arc formed during Eocene to early Miocene time (Wilson, 1985). It is best exposed on the northwest side of the Aleutian Range, in the southern part of the study area. Basaltic and andesitic calc-alkaline volcanic rocks of the Meshik Formation, volcaniclastic nonmarine sedimentary rocks of the upper part of the Tolstoi Formation, and the Bear Lake Formation, constitute the Meshik arc on the west side of the study area. The Paleocene and Eocene Tolstoi Formation in the study area is a nonmarine clastic unit, whereas the Miocene Bear Lake Formation is primarily a nearshore marine deposit containing some nonmarine rocks. Much of the area along the Pacific coast in the southern part of the study area, mapped as Mesozoic sedimentary rocks, contains numerous hypabyssal dikes and sills too small to be shown at the 1:250,000 scale in the published maps.

Further calc-alkaline magmatism occurred during late Miocene to Quaternary time (Wilson and Shew, 1988) to form the bulk of the plutons exposed throughout the area. Quaternary volcanism produced the volcanic peaks and stratovolcanoes that dominate the landscape. Most of the young volcanoes lie behind the axis of the Aleutian Range and they form two northeast-trending segments, one in the southern Ugashik quadrangle and a second segment near the south shore of Becharof Lake. Late Miocene and Pliocene intrusive rocks intrude folded Mesozoic sedimentary rocks along the Pacific coastline. Aeromagnetic studies (Case and others, 1988) suggest that other plutons may be present in the subsurface.

The overall geologic structure of the Alaska Peninsula north of Wide Bay is a gentle, broad arch, the axis of which parallels the Bruin Bay fault. Gentle anticlines and synclines are superimposed on this broad arch. South of Wide Bay, structures are much tighter and anticlines are aligned in a northeast-trending echelon pattern. The folding and extensive intrusive activity has deformed rocks as young as Pliocene (Burk, 1965, p. 137). Normal faulting, largely associated with folding, has caused numerous offsets in the older lithologic contacts.

MINERAL OCCURRENCES ON THE ALASKA PENINSULA

Known mineral occurrences on the Alaska Peninsula are dominated by porphyry copper-molybdenum deposits and associated hydrothermal vein systems (Hollister, 1978, p.72). In addition to the porphyry systems known prior to our work in the area (MacKevett and Holloway, 1977), mineralized areas on Cape Kilokak and David Island have been located. MacKevett and Holloway (1977) listed several new occurrences in the southern part of the study area during initial reconnaissance geologic work by the U.S. Geological Survey in 1976. Detra and others (1982) reported the geochemical patterns surrounding the Mike and Rex prospects and briefly described the mineralized ground at these localities.

In the Chignik-Sutwik Island study area located immediately to the south, Cox and others (1981) and Wilson and Cox (1983) described porphyry systems associated with early Tertiary to Quaternary intrusive rocks of intermediate composition which intrude marine and nonmarine clastic rocks. Copper- and molybdenum-rich porphyry systems are characterized by drainage basins having stream-sediment copper-molybdenum-tungsten anomalies surrounded by drainage basins with stream sediments anomalous in lead, zinc, bismuth, arsenic, and precious metals. Drainage-basin anomalies show overlapping, zoned geochemical patterns. Rocks exposed in these basins typically contain argillic, sericitic, or phyllic alteration associated with veins and disseminated molybdenite, chalcopyrite, and scheelite. Surrounding the exposures of intense alteration are zones of propylitic alteration containing both disseminated and vein pyrite with lesser amounts of galena, sphalerite, arsenopyrite, precious metals, barite, and some tourmaline. Minor gold is commonly associated with the porphyry systems and some placer gold may be found in streams surrounding these systems. Weathering and oxidation of exposed pyrite commonly produces characteristic yellow-brown and reddish colored anomalies. Our observations indicate that similar geologic and geochemical features are associated with possible mineralized areas in the Ugashik-Karluk study area.

Mineral exploration, prospects, and occurrences

Exploration and mining activity in the Ugashik-Karluk study area began in the early 1900's. Several major mining companies conducted regional exploration studies during the 1970's (Hollister, 1978, p. 69-76), but none are currently active in the area. As a result of these regional exploration activities, Bear Creek Mining Company (Kennecott Corporation) drilled a porphyry molybdenum prospect, known as the Mike prospect, in 1977; however, they did not pursue development of the property. A summary of their studies at the Mike prospect is given in Church, Frisken, and Wilson (1989). Nine lode prospects known prior to our work in the study area are summarized in table 1 and located on map A.

MacKevett and Holloway (1977) describe 13 placer claims, 11 of which were for gold, in the Ugashik-Karluk study area (table 2, map A). The only recorded production from these claims came from the Cape Kubugakli claim (table 2, claim 10) where Smith (1925) reported production of an estimated 5 kg (160 oz) of placer gold between 1915-23. A check of the status of mining claims showed no active placer mining claims in the Ugashik-Karluk study area (U.S. Bureau of Land Management, written commun., 1983).

METALLIC MINERAL RESOURCES

The mineral resource assessment of the Ugashik-Karluk study area is based on an integrated interpretation of the geology (Detterman, Case,

Tertiary and Quaternary volcanic-plutonic environment

Most of the mineralization seen in the field or explored by previous workers is related to the intrusion of plutons into the overlying volcanic or sedimentary host rocks. In evaluating possible mineral deposits from this environment, the following mineral deposit models were utilized, based on the geologic, geochemical, and geophysical attributes of the mineral deposit type as defined in Cox and Singer (1986). Mineral deposit models which were considered are based on our field observations and laboratory data:

(1) porphyry copper (Cox, 1986a, deposit model 17),
(2) porphyry copper-gold (Cox, 1986b, deposit model 20c),
(3) porphyry molybdenum, low-fluorine (Theodore, 1986, deposit model 21b),
(4) volcanic-hosted copper-arsenic-antimony (Cox, 1986c, deposit model 22a),
(5) polymetallic veins (Cox, 1986d, deposit model 22c),
(6) iron skarn (Cox, 1986f, deposit model 18d) or tungsten skarn (Cox, 1986g, deposit model 14a),
(7) epithermal gold (Mosier, Sato, and others, 1986, deposit model 25b; Mosier, Berger, and Singer, 1986, deposit model 25d), and
(8) carbonate-hosted gold or Carlin-type disseminated gold (Bagby and Berger, 1985; Berger, 1986, deposit model 26a).

Tracts which appear favorable for the occurrence of these deposit types are outlined on map A and the deposit model types considered favorable for each tract are summarized in table 4. All of the mineralized areas summarized in table 3 lie within the tracts outlined on map A.

Tract A1, which includes much of the southeastern plutonic province defined by Case and others (1988), is largely contiguous with mineral resource tract A from the Chignik-Sutwik Island study area to the south (Cox and others, 1981). For the purposes of discussion, this tract has been subdivided into tracts A1a and A1b. The northwest part of the tract, A1a, which consists of Mesozoic marine sedimentary rocks, is separated by a thrust fault from the southeast part of the tract. Within tract A1a, we describe mineralized rock at the Mike prospect associated with a Pliocene intrusion (table 3). The rocks in the area are intensely altered surrounding this prospect. A strongly silicified core area is surrounded by a zone of phyllic-sericitic alteration which is in turn surrounded by a zone of propylitic alteration. Extensive work has been done by Kennecott Corporation at the Mike prospect, a porphyry molybdenum, low-fluorine mineral deposit; they also reported a small copper skarn occurrence associated with the Mike prospect. On the basis of the low grade (0.35 percent copper) and inferred small size of this occurrence (Kennecott Corporation, written commun., 1987), and the low abundance of carbonate in the sedimentary rocks in tract A1, we have not considered the copper skarn mineral deposit model (Cox, 1986e; Singer, 1986b) in our assessment of mineral deposit types for the Ugashik-Karluk study area.

In tract A1b, which is underlain dominantly by early Tertiary nonmarine rocks, we have described four mineralized areas (table 3). The eastern part of tract A1b is composed of both Mesozoic and early Tertiary nonmarine rocks that have been intruded by plutonic rocks ranging in age from Oligocene to Pliocene. The rocks surrounding these small stocks west of the Agripina Bay batholith show seritic and (or) propylitic alteration. The hornfelsed rocks along the western edge of the Agripina Bay batholith are also altered and contain geochemical anomalies indicative of hydrothermal vein systems. We have also included the Agripina Bay batholith in this tract because mineralized ground in the Chignik-Sutwik Island study area to the south occurs in rocks of the same age (Wilson and Cox, 1983). Geochemical anomalies within the batholith are small and evidence of alteration is limited. Mineralized areas exposed near Mt. Chiginagak and in the area of Kilokak Creek have many of the same attributes (table 3).

Mineralized rock exposed on David Island (table 3) has the field characteristics of a volcanic-hosted copper-arsenic-antimony deposit (Church, Frisken, and Wilson, 1989). Geochemical data indicate low values for both base and precious metals. Volcanic rocks exposed at the shoreline are pervasively silicified, and massive pyritic lodes are exposed along the beach at the southwest end of the island.

Based on the geochemical anomalies and geologic criteria, we considered tract A1 permissive for the occurrence of porphyry molybdenum, low-fluorine, porphyry copper, volcanic-hosted copper-arsenic-antimony, epithermal gold, and polymetallic vein mineral deposits.

Tract A2 outlines the areal extent of Oligocene plutons and hypabyssal rocks that primarily intrude the nonmarine Tolstoi and Meshik Formations, and the marine Chignik and "Naknek" Formations. The tract is defined by the extent of intrusive activity associated with the Rex prospect (table 3) based on geologic mapping (Detterman, Case, and others, 1987) and aeromagnetic data (Case and others, 1988). Zoned potassic, phyllic, and propylitic alteration surround the prospect. Unpublished geochemical data from Kennecott Corporation indicates that this is a porphyry copper-gold system. They projected the gold grade of this mineralized area to be about 0.7 g gold per ton at 1 percent copper based on a surface rock sampling program; some areas showed copper grades above 0.1 percent (Kennecott Corp., written commun., 1987; published with permission). Based on the geochemical anomalies and geologic criteria, we considered tract A2 permissive for the occurrence of porphyry copper-gold and associated epithermal gold mineral deposits, as well as for polymetallic vein deposits.

Tract A3 is underlain by nonmarine clastic sedimentary rocks of the Tolstoi Formation, which overlie marine clastic rocks of the Chignik and "Naknek" Formations. The tract is defined by the geologic extent of hypabyssal dikes of Oligocene age that intrude tract A3, and by the outlines of drainage basins containing geochemically anomalous samples (map A) associated with tract A3. Sericitic alteration was observed in the upper reaches of Painter Creek (table 3). Geophysical data (Case and others, 1988) suggest that a pluton may exist at depth. Based on the geochemical anomalies and geologic criteria, we considered tract A3 permissive for the occurrence of both epithermal gold and polymetallic vein mineral deposits.

Tract A4 is defined largely on the basis of the inferred extent of a Pliocene pluton (Detterman, Case, and others, 1987) exposed at Cape Igvak. The tract is open offshore and, on the basis of the aeromagnetic map (Case and others, 1988), may include the two magnetic highs to the south. The quartz diorite pluton exposed at Cape Igvak intruded the Jurassic marine sedimentary rocks of the Shelikof and "Naknek" Formations and has propylitically altered the country rocks. The intrusion crosscuts the siltstone member of the Shelikof Formation which contains thin beds of carbonate as well as carbonate cement in the siltstone (Detterman, Case, and others (1987). On the basis of geochemical anomalies and geologic criteria (table 3), we considered tract A4 permissive for the occurrence of porphyry copper, iron skarn, carbonate-hosted gold (Carlin-type), and polymetallic vein mineral deposits.

Two large claim blocks for iron lodes (table 1, nos. 3 and 4) have

Although not examined in the field, the geologic and geochemical evidence suggest that an iron deposit may be present in tract A4. Two large claim blocks were staked in tract A4; both claim blocks are associated with high magnetic anomalies and magnetite is abundant in the intrusive rocks and in the stream drainages. On the basis of our geochemical data and comparison with the grade/tonnage curves for iron skarns (Mosier and Menzie, 1986), we estimate a 10 percent chance of one or more undiscovered iron skarn deposits in the Ugashik-Karluk study area.

Mineralized rock exposed on David Island (table 3) has the field characteristics of a volcanic-hosted copper-arsenic-antimony deposit (Church, Frisken, and Wilson, 1989). Pyritic lodes are exposed along the beach at the southwest end of the island. However, the geochemical data indicate low values for both base and precious metals. No grade/tonnage curves are available for this type of deposit model because so few deposits of this type have been found, however, the geologic environment for this deposit model type is present in several of the tracts defined above.

Estimates of the number of undiscovered deposits for epithermal gold, for carbonate-hosted gold, and for polymetallic vein mineral deposit models are subject to a large uncertainty due to the reconnaissance nature of this study. These types of deposits have a much smaller geologic and geochemical expression than the larger porphyry mineral deposit systems. Geologic, geophysical, and geochemical evidence for these mineral deposit types occur in several of the tracts outlined on map A (table 4), and the mineral deposit models have been applied to mineralized areas summarized in table 3 as associated mineral deposits. Tracts having favorable geologic and geochemical criteria for the occurrence of this type of mineralization are summarized in table 4.

Evaluation of placer resources in the Quaternary glacial and alluvial environment

The Quaternary glacial-alluvial environment has been investigated for possible placer accumulations of minerals along the tributaries of the major streams. Evidence of the accumulation of gold in the panned concentrates is sparse except for the area around the Rex prospect where Frisken, Church, and Willson (1988) reported several flakes of gold in the panned concentrates from every tributary. The source of placer gold around the Rex prospect is presumed to be the porphyry copper system defined in tract A2. Where these tributaries change gradient abruptly as they enter the larger streams on the Nushagak-Bristol Bay Lowland, conditions are favorable for the accumulation of small placers (Yeend, 1986). The intersection of these tributaries with Volcano Creek on the south, with Wandering Creek on the east, or with the small streams in the headwaters of the Dog Salmon River as well as glacial lake terraces along the north side of the Rex prospect (Detterman, Wilson, and others, 1987) represent areas of possible accumulation for small gold placer deposits.

In our reconnaissance geochemical studies of the Cape Kubugakli area, we detected visible gold in the heavy-mineral concentrates. A sluice box was seen on the bluff above the claims. Gold was also detected in the geochemical studies of tract A8, but the mineralized area seems to be small. Smith (1925) reported gold production from this locality on claims filed by Fred and Jack Mason in 1915 (table 2). Gold was confined to one creek and further exploration by the early prospectors failed to locate additional drainages containing placer gold. Smith (1925) reported a stream width of 2-3 m with an average depth of gravel of about 0.5 m to bedrock at the Mason claims on Cape Kubugakli. Because of the short, steep nature of the drainage and the presence of large boulders in the stream bed, we cannot expect that substantive reserves of placer gold might be produced on Cape Kubugakli or in the surrounding area (Orris and Bliss, 1986). Marine terraces at Cape Kubugakli may also contain some placer gold (Detterman, Wilson, and others, 1987).

We sampled the magnetite-bearing lenses of sandstone, primarily from the "Naknek" Formation, and analyzed them for gold to evaluate them as a source for placer gold. Analyses of 31 samples of this material failed to detect any gold using flame atomic absorption methods (O'Leary and Meier, 1986; detection limit, 0.05 ppm). We conclude that these heavy-mineral-rich lenses within the "Naknek" Formation are not a major source of placer gold in the study area. We observed no gold and did not detect any anomalous gold concentrations in heavy-mineral concentrates collected from drainage basins within the "Naknek" Formation. Placer gold deposits along streams draining areas where the "Naknek" Formation is the major source of heavy minerals (table 2, map nos. 12-17, 19, 20) are considered mineral occurrences. Placer gold in the drainages near the eastern end of Becharof Lake (table 2, map no. 11) was not evaluated. In general, based on the deposit model for placer accumulations in streams (Orris and Bliss, 1986), placer accumulations either for gold or other commodities in the Ugashik-Karluk study area are not expected to become a mineral resource because of the low metal content and small size of the alluvial deposits.

Berryhill (1963, p. 31-33) investigated the beach sands found along the Bering Sea coast south of the mouth of the Cinder River (table 2, map no. 22). He collected 15 auger samples, spaced at 1 mi (1.6 km) intervals, from the black beach sands in this area. Recovery ranged from 0.01 to 0.02 m^3 of material from each site. Panned concentrates prepared from these samples all contained more than 10 percent titaniferous magnetite and pyroxene, and two sites contained flour gold. The TiO_2 content from the Cinder River area black sands ranged from 0.9 to 3.5 kg of TiO_2/m^3. Berryhill (1963) concluded that the beach placers (table 2, map nos. 21-22) along the Bristol Bay coast were not a resource for either TiO_2 or gold. Comparison of the grades of these deposits (0.1-0.2 percent TiO_2/ton) with the grade and tonnage curves for TiO_2 from producing beach placer deposits (ninety percent of the producing deposits have grades in excess of 5 percent TiO_2/ton, Attanasi and DeYoung, 1986) indicates that the Bristol Bay beach placers can only be considered a mineral occurrence. Similar studies of the black sands exposed along the Pacific coast from Dry Bay to Portage Bay and along the shoreline of Wide Bay have not been carried out. However, analysis of magnetite-rich fractions of panned concentrates from the Cape Igvak area indicate a much lower concentration of TiO_2 and a much lower recovery of magnetite in these streams. It appears unlikely that the black sands on the beach between Cape Igvak and Portage Bay is more than a mineral occurrence.

NONMETALLIC MINERAL RESOURCES

Nonmetallic commodities considered include cinder, pumice, and limestone. Other nonmetallic commodities in abundance, but not specifically evaluated as resources include deposits of sand and gravel. Inferred resources for some of the commodities are listed in table 5 and tracts favorable for the occurrence of nonmetallic resources are delineated on map B. The large pumice resource outlined at Aniakchak Volcano (tract B1) is only a part of the deposit which extends into the adjoining Chignik quadrangle (Detterman and others, 1981). Minor amounts of the pumice in the Chignik quadrangle were used for road and airfield construction at Meshik and Port Heiden. No production of

study area also support this conclusion. Diagenetic alteration of the abundant volcanic debris with the formation of zeolites and the weathering of feldspars to clay has greatly restricted reservoir potential. Locally, some of the sandstones in the lower part of the "Naknek" Formation have good porosity and permeability. Bioherms in the Triassic limestone probably have good porosity, but with available data, the locations of these structures in the subsurface are unpredictable. The organic carbon content of the Mesozoic rocks is good and oil has been generated as evidenced by small oil seeps. The lack of commercial oil production from these wells may reflect the poor reservoir characteristics.

Numerous CO_2-rich gas seeps in Becharof Lake adjacent to The Gas Rocks are thought to be of mantle origin. Analysis of gas from The Gas Rocks vent in Becharof Lake shows about 97 percent CO_2 with a carbon isotopic signature of $\delta^{13}C$ of -6.36 per mil, outside the range of carbon isotopic values permissable for organic carbon (Barnes and McCoy, 1979). Other natural gas seeps are reported by Blasko (1976), some of which are associated with oil seeps and are thought to be of thermogenic origin.

Overall, the oil and gas potential for the Mesozoic rocks from tract E2 in the Ugashik-Karluk study area is considered to be low. Oil and gas are present, but the poor reservoir characteristics greatly diminish any potential for economic production.

Coal Resources

Coal and lignite-bearing beds are present in the lower part of the Tolstoi Formation along the southern border of the study area. Three tracts containing coal are shown on map B. Spot observations were made at several localities but the lateral extent is unknown. The quality of the coal was not confirmed by independent analysis, but field observations indicate a range from subbituminous to anthracite. The anthracite occurs near small igneous intrusions. Numerous thin seams, mainly from 2 to 15 cm thick, occur in tracts E3 and E4 (map B). Tract E5 (map B) has several beds 1-2 m thick that were seen on traverses 5 km apart. If the thickness of the coal seams is consistent between these two points, they might have economic potential.

Finally, geologic conditions are permissive for the formation of graphite in the zones of contact metamorphism the coal resource tracts. Segura (1985, p. 10-12) reports that the graphite deposits found in the area of San Jose deMoradillas, Tonichi, and the Alamos mines where formed by contact metamorphism of Triassic(?) sediments containing coal beds. These deposits have large reserves (greater than 1 million tons) of graphite with a grade in excess of 80 percent carbon. Segura (1985) also reports the presence of andelusite in the pelitic rocks in the contact metamorphic zones in Sonora indicating pyroxene hornfels metamorphic grade. In most of the contact metamorphic zones in the Ugashik-Karluk study area, only micas were observed. We have no evidence that the contact metamorphism in tract E5 approached the temperatures of the pyroxene hornfels metamorphic grade. The graphite potential in zones of contact metamorphism in the three coal tracts is low.

SUMMARY AND CONCLUSIONS

On the basis of our geologic mapping, regional geochemical sampling, geophysical studies, and evaluation of mines and prospects as well as studies of newly defined mineralized areas, we have provided an assessment of the metallic and nonmetallic mineral and energy resources of the Bristol Bay, Ugashik, and western Karluk quadrangles. We have outlined eight tracts of ground having defined metallic mineral resources (Map A). The deposit types considered in each tract are summarized in table 4. Most of the deposit model types described are based on mineralized areas investigated in the Ugashik-Karluk study area (tables 1-3) or known to occur on the Alaska Peninsula, although application of the calcic iron skarn and the carbonate-hosted gold deposit models are based on permissive geologic, geochemical, and geophysical evidence.

Estimates of the number of undiscovered deposits, by deposit model type, are made for the large porphyry deposits. We estimate that there is a 10 percent chance for 2 or more porphyry copper deposits in the study area. We estimate that there is a 90 percent chance for one or more undiscovered porphyry molybdenum, low-fluorine deposit, and a 10 percent chance for the discovery of 2 or more such deposits in the southern part of the study area. We estimate that there is a 90 percent chance for the discovery of one or more porphyry-gold deposits and a 10 percent chance for the discovery of 2 or more such deposits in the study area. Finally, we estimate a 10 percent chance for the discovery of one or more iron skarn deposits in the study area. For the other types of deposits considered, the level of our knowledge of the study area was insufficient to make estimates of the numbers of undiscovered deposits. Further detailed mapping at a smaller scale would be required to make these esitmates. However, we consider the geologic, geochemical, and geophysical data permissive for these types of deposits in one or more of the metallic mineral resource tracts outlined on Map A: epithermal gold deposits associated with the porphyry systems, volcanic-hosted copper-arsenic-antimony deposits similar to those observed on David Island, carbonate-hosted gold deposits in the northeastern portion of the study area where plutons intersect the carbonate-rich siltstone member of the Shelikof Formation, and polymetallic vein deposits peripheral to the porphyry systems.

Several placer claims for gold have been filed within the study area and one, located at Cape Kubugakli, has reported production (table 2). The geologic conditions are favorable for the accumulation of small gold placers in the marine terraces on Cape Kubugakli. Gold was seen also in the panned concentrates from stream drainages surrounding the Rex prospect (tract A2). Possible accumulations of placer gold may be present in Volcano Creek, Wandering Creek, or in the tributaries of the headwaters of the Dog Salmon River. We did not find placer gold in drainages underlain by the "Naknek" Formation.

Berryhill (1963) evaluated the TiO_2-rich beach sands along the Bristol Bay coast and concluded that these black sands constituted a mineral occurrence. Likewise, the black sands found north of Cape Igvak to Portage Bay on the eastern coastline are also considered only a mineral occurrence.

Three areas of cinder resources (Map B, tracts B1-B3) are defined. Both the cinder and the sand and gravel resources in the area are adequate for local demand. Limestone located at Cape Kekurnoi is considered marginally economic. Graphite potential associated with the contact metamorphic zone surrounding an intrusive in tract E5 is considered to be low.

The energy resources of the study area include geothermal, coal, and oil and gas. Hot springs located at Mount Chiginagak and fumarolic activity at Ukinrek Maars are strong evidence of geothermal energy at sites having the highest geothermal potential. Smith and Shaw (1975) calculated a large geothermal potential for Aniakchak Volcano located just 8 km south of the study area.

Oil and gas potential was evaluated for two large provinces. Tract E1 is the eastern margin of the Bristol Bay basin. Thermal maturation of the rocks has not been sufficient to produce commercial quantities of

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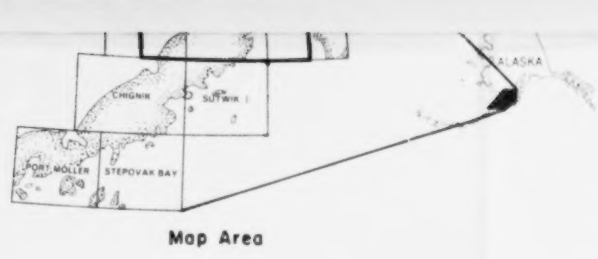
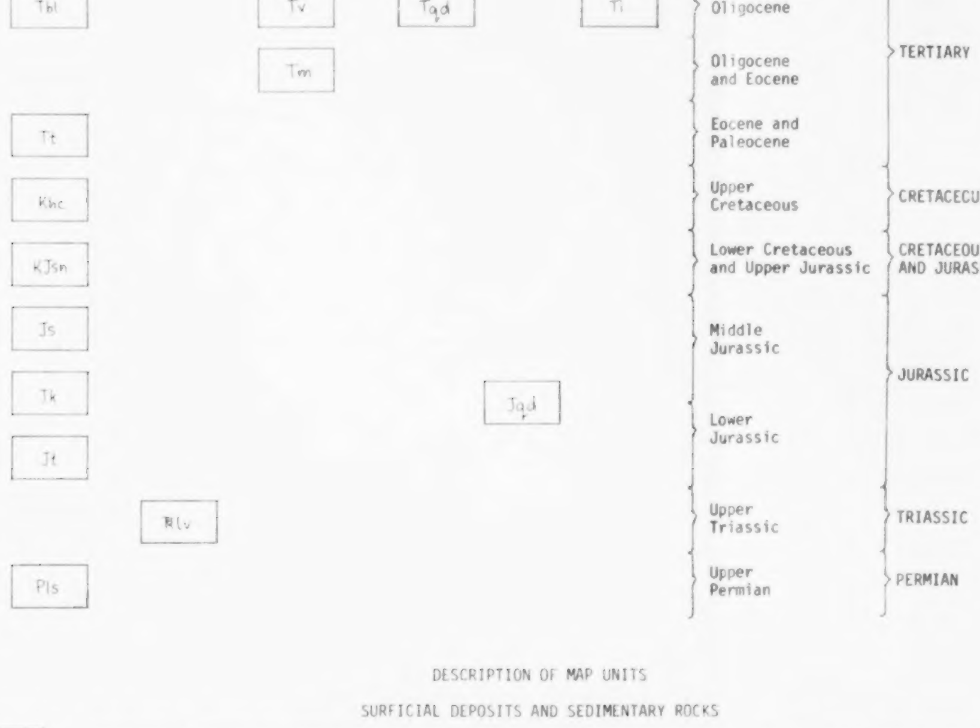
NATIONAL GEODETIC VERTICAL DATUM OF 1929

MAP A.–METALLIC MINERAL RESOURCES



Map Area

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS AND SEDIMENTARY ROCKS

Qs	SURFICIAL DEPOSITS (HOLOCENE AND PLEISTOCENE) - Unconsolidated alluvium, alluvial fans, and glacial, marine, lake, swamp, eolian, and landslide deposits; mainly silt, sand, gravel, pumice, and rock fragments
Tbl	BEAR LAKE FORMATION (MIOCENE) - Sandstone, siltstone, shale, minor coal, and conglomerate; nonmarine
Tt	TOLSTOI FORMATION (EOCENE AND PALEOCENE) - Sandstone, conglomerate, siltstone, shale, coal, and tuff; dominantly volcaniclastic and nonmarine
Khc	HOODOO AND CHIGNIK FORMATIONS, UNDIVIDED (UPPER CRETACEOUS) - Hoodoo Formation: dark rhythmically-bedded siltstone and shale, minor thin sandstone; deep-water marine. Chignik Formation: sandstone, conglomerate, siltstone, and shale; mainly shallow marine
KJsn	STANIUKOVICH AND NAKNEK FORMATIONS, UNDIVIDED (LOWER CRETACEOUS AND UPPER JURASSIC) - Staniukovich Formation of Late Jurassic and Early Cretaceous age: thin-bedded feldspathic sandstone, commonly laumontitic; minor siltstone and shale. Naknek Formation of Late Jurassic age: thin-bedded sandstone, siltstone, and dark shale with limestone concretions in upper part. Massive arkosic sandstone and conglomerate in lower part; abundant granitic- and metamorphic-rock clasts in conglomerate. Upper part marine; lower part nonmarine fluvial
Js	SHELIKOF FORMATION (MIDDLE JURASSIC) - Dark siltstone and shale with limestone concretions, sandstone, and conglomerate; nonmarine to near-shore marine, and deep-water turbidite
Jk	KIALAGVIK FORMATION (MIDDLE AND LOWER JURASSIC) - Sandstone, siltstone, mudstone, and shale; mainly shallow water marine
Jt	TALKEETNA FORMATION (LOWER JURASSIC) - Tuffaceous sandstone, siltstone, and limestone; minor bedded tuff
Pls	LIMESTONE (UPPER PERMIAN) - Light-gray massive crystalline limestone

SEDIMENTARY AND VOLCANIC ROCKS

R̄lv	LIMESTONE AND VOLCANIC ROCKS (UPPER TRIASSIC) - Light- to dark-gray thin-bedded to massive limestone, limestone conglomerate, and basalt

VOLCANIC ROCKS

Qv	VOLCANIC ROCKS (HOLOCENE AND PLEISTOCENE) - Block and ash flows, debris flows, volcanic mud flows, cinder cones, and andesitic and dacitic lava flows; includes minor hypabyssal rocks
Tv	VOLCANIC ROCKS (PLIOCENE TO OLIGOCENE) - Basalt, andesite, and dacite lava flows, volcanic breccia, and rubble flows; locally includes hypabyssal rocks
Tm	MESHIK FORMATION (OLIGOCENE AND EOCENE) - Basalt flows, volcanic rubble flows, and lahars; locally minor volcanogenic sedimentary rocks

INTRUSIVE ROCKS

Tqd	QUARTZ DIORITE (PLIOCENE TO OLIGOCENE) - Agripina Bay pluton; hornblende-biotite and pyroxene-biotite quartz diorite; medium to coarse grained
Ti	INTRUSIVE ROCKS (PLIOCENE TO OLIGOCENE) - Diorite, quartz diorite, hypabyssal andesite and dacite
Jqd	QUARTZ DIORITE (MIDDLE AND LOWER JURASSIC) - Medium to coarse grained, hornblende and biotite bearing; part of the Alaska-Aleutian Range batholith

CONTACT--Dotted where concealed

U
D
FAULT--Dotted where concealed; queried where probable. U, upthrown side; D, downthrown side. Arrows indicate relative lateral movement

THRUST OR HIGH-ANGLE REVERSE FAULT--Dotted where concealed; sawteeth on upper plate

FOLDS--Showing trace of axial plane; dotted where concealed; queried where probable. Arrow indicates direction of plunge

Anticline

Syncline

LINEAMENT

VOLCANIC CRATER

VOLCANIC VENT OR CINDER CONE (OTHER THAN WITHIN CRATERS)

HORNFELS

ALTERATION--Includes sericitic alteration and silicification

EXPLORATORY DRILL HOLE

OIL SEEPS

HOT SPRING

COLD SPRING

GAS SEEP--Carbon dioxide

INTRODUCTION

The U.S. Geological Survey is required by the Alaska National Interest Lands Conservation Act (ANILCA, Public Law 96-487) to survey certain Federal lands to determine their mineral resource potential. As a part of the Alaska Mineral Resource Assessment Program (AMRAP), a multimedia, multidisciplinary study of the geology, geophysics, and the geochemistry of the Ugashik, Bristol Bay, and western Karluk quadrangles was undertaken during the summers of 1979-82. Two days of additional field work were done in the summer of 1986. This report presents a summary of the metallic and nonmetallic mineral and energy resources of the Ugashik, Bristol Bay, and western Karluk quadrangles, Alaska.

Land Status

Much of the acreage in the Ugashik-Karluk study area, particularly along the Alaska-Aleutian Range, lies in the Alaska Peninsula and Becharof National Wildlife Refuges, and the Aniakchak National Monument and Preserve. The Katmai National Park and Preserve extends into the western Karluk quadrangle, and the State of Alaska has small land holdings on the west side of Wide Bay as well as along the Bristol Bay coast. Two native corporations also have land holdings in the study area. Koniag Incorporated holds a small strip of land in T. 37 S. partway across the southern portion of the study area. Bristol Bay Native Corporation has land holdings in the Nushagak-Bristol Bay Lowland (Wahraftig, 1965) along the main drainages of the Ugashik and Dog Salmon Rivers inland to Lower Ugashik Lake. There are also private land holdings around Ugashik Bay and inland along the Ugashik, Dog Salmon, and King Salmon Rivers (U.S. Bureau of Land Management, 1987).

GEOLOGY OF THE UGASHIK-KARLUK STUDY AREA

Geologic mapping in the Ugashik-Karluk study area by Detterman and others (1983) forms the geologic base for this report. The oldest rocks exposed in the Ugashik-Karluk study area are Permian limestone (Hanson, 1957) that crop out on a small island offshore of Cape Kekurnoi on the Pacific Coast. On shore, there are limited outcrops of Triassic limestone, shale, and minor clastic and volcanic rock that were deposited in a shallow-water, quiet basin environment. The Triassic rocks are exposed along the Pacific Coast at Puale Bay and to the north toward Alinchak Bay.

The Alaska-Aleutian Range batholith of Jurassic, Cretaceous, and early Tertiary age (Reed and Lanphere, 1969, 1973) only crops out on a small island in Becharof Lake. This outcrop has been dated using K-Ar determinations on hornblende and biotite separates at 172 and 176 Ma, respectively (Reed and Lanphere, 1969). The Jurassic plutonic rocks of the batholith were emplaced to form the core of the Alaska Peninsula and are, in part, contemporaneous with the Lower Jurassic Talkeetna Formation, which consists of volcanic rocks and tuffaceous sandstone, and the Lower and Middle Jurassic Kialagvik Formation which consists of shallow-water marine sandstone and shale. Later, the Middle Jurassic Shelikof Formation, composed of volcanically derived sandstone, conglomerate, siltstone, shale, and minor deep-water turbidite, was deposited. Rocks of the Shelikof Formation are exposed along the Pacific Coast of the study area and the Kialagvik Formation is exposed at Wide Bay on the axis of the anticline centered in Wide Bay and at Puale Bay (Allaway and Miller, 1984). During Late Jurassic time, the Staniukovich and Naknek Formations, which were derived from the erosion of the Alaska-Aleutian Range batholith, were deposited. The lower conglomeratic part of the Naknek Formation was deposited in a nonmarine fluvial environment, whereas the upper sandstone and shale units, containing limestone concretions, represent a marine environment. Detterman, Case, and others (1987) suggested that the rocks mapped as the Staniukovich Formation in the study area represent essentially continuous sedimentation and may be best considered to be a member of the Naknek Formation. Throughout the discussion in this paper, we will use the term "Naknek" Formation to include these rocks. Overlying these rocks is the Chignik Formation of Late Cretaceous age which was deposited in a cyclical fluvial to nearshore marine sedimentary environment (Detterman, 1978). The Cretaceous Hoodoo Formation interfingers with and overlies the Chignik Formation and is a turbidite indicating a deeper-water environment.

The Meshik arc formed during Eocene to early Miocene time (Wilson, 1985). It is best exposed on the northwest side of the Aleutian Range, in the southern part of the study area. Basaltic and andesitic calc-alkaline volcanic rocks of the Meshik Formation, volcaniclastic nonmarine sedimentary rocks of the upper part of the Tolstoi Formation, and the Bear Lake Formation, constitute the Meshik arc on the west side of the study area. The Paleocene and Eocene Tolstoi Formation in the study area is a nonmarine clastic unit, whereas the Miocene Bear Lake Formation is primarily a nearshore marine deposit containing some nonmarine rocks. Much of the area along the Pacific coast in the southern part of the study area, mapped as Mesozoic sedimentary rocks, contains numerous hypabyssal dikes and sills too small to be shown at the 1:250,000 scale in the published maps.

Further calc-alkaline magmatism occurred during late Miocene to Quaternary time (Wilson and Shew, 1988) to form the bulk of the plutons exposed throughout the area. Quaternary volcanism produced the volcanic peaks and stratovolcanoes that dominate the landscape. Most of the young volcanoes lie behind the axis of the Aleutian Range and they form two northeast-trending segments, one in the southern Ugashik quadrangle and a second segment near the south shore of Becharof Lake. Late Miocene and Pliocene intrusive rocks intrude folded Mesozoic sedimentary rocks along the Pacific coastline. Aeromagnetic studies (Case and others, 1988) suggest that other plutons may be present in the subsurface.

The overall geologic structure of the Alaska Peninsula north of Wide Bay is a gentle, broad arch, the axis of which parallels the Bruin Bay fault. Gentle anticlines and synclines are superimposed on this broad arch. South of Wide Bay, structures are much tighter and anticlines are aligned in a northeast-trending echelon pattern. The folding and extensive intrusive activity has deformed rocks as young as Pliocene (Burk, 1965, p. 137). Normal faulting, largely associated with folding, has caused numerous offsets in the older lithologic contacts.

MINERAL OCCURRENCES ON THE ALASKA PENINSULA

Known mineral occurrences on the Alaska Peninsula are dominated by porphyry copper-molybdenum deposits and associated hydrothermal vein systems (Hollister, 1978, p.72). In addition to the porphyry systems known prior to our work in the area (MacKevett and Holloway, 1977), mineralized areas on Cape Kilokak and David Island have been located. MacKevett and Holloway (1977) listed several new occurrences in the southern part of the study area during initial reconnaissance geologic work by the U.S. Geological Survey in 1976. Detra and others (1982) reported the geochemical patterns surrounding the Mike and Rex prospects and briefly described the mineralized ground at these localities.

In the Chignik-Sutwik Island study area located immediately to the south, Cox and others (1981) and Wilson and Cox (1983) described porphyry systems associated with early Tertiary to Quaternary intrusive rocks of intermediate composition which intrude marine and nonmarine clastic rocks. Copper- and molybdenum-rich porphyry systems are characterized by drainage basins having stream-sediment copper-molybdenum-tungsten anomalies surrounded by drainage basins with stream sediments anomalous in lead, zinc, bismuth, arsenic, and precious metals. Drainage-basin anomalies show overlapping, zoned geochemical patterns. Rocks exposed in these basins typically contain argillic, sericitic, or phyllic alteration associated with veins and disseminated molybdenite, chalcopyrite, and scheelite. Surrounding the exposures of intense alteration are zones of propylitic alteration containing both disseminated and vein pyrite with lesser amounts of galena, sphalerite, arsenopyrite, precious metals, barite, and some tourmaline. Minor gold is commonly associated with the porphyry systems and some placer gold may be found in streams surrounding these systems. Weathering and oxidation of exposed pyrite commonly produces characteristic yellow-brown and reddish colored anomalies. Our observations indicate that similar geologic and geochemical features are associated with possible mineralized areas in the Ugashik-Karluk study area.

Mineral exploration, prospects, and occurrences

Exploration and mining activity in the Ugashik-Karluk study area began in the early 1900's. Several major mining companies conducted regional exploration studies during the 1970's (Hollister, 1978, p. 69-76), but none are currently active in the area. As a result of these regional exploration activities, Bear Creek Mining Company (Kennecott Corporation) drilled a porphyry molybdenum prospect, known as the Mike prospect, in 1977; however, they did not pursue development of the property. A summary of their studies at the Mike prospect is given in Church, Frisken, and Wilson (1989). Nine lode prospects known prior to our work in the study area are summarized in table 1 and located on map A.

MacKevett and Holloway (1977) describe 13 placer claims, 11 of which were for gold, in the Ugashik-Karluk study area (table 2, map A). The only recorded production from these claims came from the Cape Kubugakli claim (table 2, claim 10) where Smith (1925) reported production of an estimated 5 kg (160 oz) of placer gold between 1915-23. A check of the status of mining claims showed no active placer mining claims in the Ugashik-Karluk study area (U.S. Bureau of Land Management, written commun., 1983).

METALLIC MINERAL RESOURCES

The mineral resource assessment of the Ugashik-Karluk study area is based on an integrated interpretation of the geology (Detterman, Case, and others, 1987), the aeromagnetic map (Case and others, 1988), geochronological and major element chemical data (Wilson and Shew, 1988), geochemical studies (Detra and others, 1981; Church and others, 1988; Church, Frisken, and Wilson, 1989; Frisken, Church, Detra and Willson, 1988; Wilson and O'Leary, 1986, 1987), and the mineralogy maps of the nonmagnetic heavy-mineral concentrates panned from stream sediments (Frisken, Church, and Willson, 1988) included in the Ugashik-Karluk folio. These data form the basis for the interpretations made in this report. On map A, outlines of the drainage basins containing anomalous concentrations of copper and molybdenum and (or) tungsten, as well as surrounding basins containing anomalous concentrations of lead, zinc, silver, gold, arsenic, bismuth, cadmium, and tin, are shown. This group of elements was selected to target areas of porphyry-copper-type mineralization and associated deposits. In table 3, we summarize the geologic, geochemical, and geophysical attributes of selected mineral occurrences within the study area. These occurrences form the data base from which deposit model types were determined and form the basis from which our estimates of the number of undiscovered deposits within the study area were made. The mineral resource assessment is presented using terminology for mineral deposit models and deposit model numbers defined in Cox and Singer (1986). Eight tracts, which are favorable for the occurrence of mineral resources, are summarized in table 4 and outlined on map A. No resource estimates were made for possible deposits which might be buried more than 1 km deep.

Permian and Triassic carbonate depositional environment

The oldest sedimentary rocks in the study area, the Permian limestones exposed on an island at the mouth of Puale Bay, and the Triassic limestones exposed along the coast at Cape Kekurnoi have very limited exposures. We observed no field evidence of mineralized rock and did not detect any geochemical anomalies that could be related to these rocks. No syngenetic deposits are associated with the shallow-water reef depositional environment represented by these rocks.

Late Triassic and Early Jurassic volcanic environment

Upper Triassic volcanic rocks also crop out at Cape Kekurnoi (Detterman, Case, and others, 1987) where they intrude and overlie the Triassic limestones. Basaltic pillow lavas interbedded with volcanic breccias and volcaniclastic debris flows indicate that they were extruded in a shallow-water submarine environment permissive for the occurrence of volcanogenic massive sulfide deposits (Singer, 1986a). However, field mapping and geochemical sampling in the study area failed to locate any evidence for the occurrence of massive sulfides in these rocks.

Lower Jurassic tuffaceous limestone, tuff, and shale of the Talkeetna Formation overlie the volcanic rocks at Cape Kekurnoi. One drainage basin containing outcrops of these rocks contains anomalous silver and barium. No copper, zinc, lead, or gold anomalies were observed associated with these rocks.

Jurassic and Cretaceous sedimentary environment

The clastic rocks of the Kialagvik, Shelikof, and Naknek Formations represent deposition in a continental-shelf sedimentary basin. The Shelikof Formation contains dominately volcanic clasts whereas the Naknek Formation contains numerous clasts, predominantly of plutonic rocks. Taken together, the sedimentary rock units indicate that they were being derived from a volcano-plutonic terrane. Fossiliferous marine rocks containing plant debris indicate a near-shore depositional environment for the Kialagvik and parts of the Naknek Formations. No syngenetic metallic mineral deposits are known to be characteristic of this environment. A few isolated copper, lead, and silver anomalies occur in panned concentrates from stream sediments taken from basins underlain by the Shelikof Formation. We detected no geochemical evidence of mineralized rock in the drainage basins near the Sulfur Creek (table 1, no. 7) or the North Fork Rex Creek (table 1, no. 6) claims. Similarly, no geochemical anomalies occur in the drainage basins in the Naknek Formation near either the Puale Bay locality (table 1, no. 8) or the Ugashik River claim (table 1, no. 5). The rocks at the head of Puale Bay are cut by dikes and sills that form weak color anomalies in this area. We conclude that no syngenetic metallic mineral deposits are associated with rocks formed in this environment. Heavy-mineral studies of the sediments derived from erosion of rocks of the Naknek Formation indicate abundant zircon in the panned concentrates and geochemistry indicates high concentrations of zirconium, niobium, and rare earth elements. Placer claim 18 (table 2) is probably on the zircon-rich sands in Salmon Creek. No economically significant concentrations of metals could be expected to occur in these rocks.

Late Cretaceous and Tertiary tuffaceous-sedimentary environment

Small exposures of the Upper Cretaceous Chignik and Hoodoo Formations occur in the southern part of the study area. These two formations represent a shallow to deep marine depositional environment. These rocks are overlain by the Tolstoi Formation of Eocene age in the mapped area, a thick-bedded continental deposit. Thirteen carbonaceous samples from these formations were analyzed for uranium to check for possible uranium roll-front deposits (Turner-Peterson and Hodges, 1986). Low uranium concentrations (0.15-0.60 ppm) and low scintillometer readings (Detterman and others, 1982) obtained during the field studies suggest that the probability for the occurrence of uranium deposits in these rocks is low. In general, the tuffaceous materials present in the Tolstoi Formation are of andesitic rather than rhyolitic compositions and are not as good a source of uranium for roll-front deposits as are the more rhyolitic tuffs. Cox and others (1981) reached similar conclusions for the Chignik-Sutwik Island study area to the south.

Tertiary and Quaternary volcanic-plutonic environment

Most of the mineralization seen in the field or explored by previous workers is related to the intrusion of plutons into the overlying volcanic or sedimentary host rocks. In evaluating possible mineral deposits from this environment, the following mineral deposit models were utilized, based on the geologic, geochemical, and geophysical attributes of the mineral deposit type as defined in Cox and Singer (1986). Mineral deposit models which were considered are based on our field observations and laboratory data:

(1) porphyry copper (Cox, 1986a, deposit model 17),
(2) porphyry copper-gold (Cox, 1986b, deposit model 20c),
(3) porphyry molybdenum, low-fluorine (Theodore, 1986, deposit model 21b),
(4) volcanic-hosted copper-arsenic-antimony (Cox, 1986c, deposit model 22a),
(5) polymetallic veins (Cox, 1986d, deposit model 22c),
(6) iron skarn (Cox, 1986f, deposit model 18d) or tungsten skarn (Cox, 1986g, deposit model 14a),
(7) epithermal gold (Mosier, Sato, and others, 1986, deposit model 25b; Mosier, Berger, and Singer, 1986, deposit model 25d), and
(8) carbonate-hosted gold or Carlin-type disseminated gold (Bagby and Berger, 1985; Berger, 1986, deposit model 26a).

Tracts which appear favorable for the occurrence of these deposit types are outlined on map A and the deposit model types considered favorable for each tract are summarized in table 4. All of the mineralized areas summarized in table 3 lie within the tracts outlined on map A.

Tract A1, which includes much of the southeastern plutonic province defined by Case and others (1988), is largely contiguous with mineral resource tract A from the Chignik-Sutwik Island study area to the south (Cox and others, 1981). For the purposes of discussion, this tract has been subdivided into tracts A1a and A1b. The northwest part of the tract, A1a, which consists of Mesozoic marine sedimentary rocks, is separated by a thrust fault from the southeast part of the tract. Within tract A1a, we describe mineralized rock at the Mike prospect associated with a Pliocene intrusion (table 3). The rocks in the area are intensely altered surrounding this prospect. A strongly silicified core area is surrounded by a zone of phyllic-sericitic alteration which is in turn surrounded by a zone of propylitic alteration. Extensive work has been done by Kennecott Corporation at the Mike prospect, a porphyry molybdenum, low-fluorine mineral deposit; they also reported a small copper skarn occurrence associated with the Mike prospect. On the basis of the low grade (0.35 percent copper) and inferred small size of this occurrence (Kennecott Corporation, written commun., 1987), and the low abundance of carbonate in the sedimentary rocks in tract A1, we have not considered the copper skarn mineral deposit model (Cox, 1986e; Singer, 1986b) in our assessment of mineral deposit types for the Ugashik-Karluk study area.

In tract A1b, which is underlain dominantly by early Tertiary nonmarine rocks, we have described four mineralized areas (table 3). The eastern part of tract A1b is composed of both Mesozoic and early Tertiary nonmarine rocks that have been intruded by plutonic rocks ranging in age from Oligocene to Pliocene. The rocks surrounding these small stocks west of the Agripina Bay batholith show seritic and (or) propylitic alteration. The hornfelsed rocks along the western edge of the Agripina Bay batholith are also altered and contain geochemical anomalies indicative of hydrothermal vein systems. We have also included the Agripina Bay batholith in this tract because mineralized ground in the Chignik-Sutwik Island study area to the south occurs in rocks of the same age (Wilson and Cox, 1983). Geochemical anomalies within the batholith are small and evidence of alteration is limited. Mineralized areas exposed near Mt. Chiginagak and in the area of Kilokak Creek have many of the same attributes (table 3).

Mineralized rock exposed on David Island (table 3) has the field characteristics of a volcanic-hosted copper-arsenic-antimony deposit (Church, Frisken, and Wilson, 1989). Geochemical data indicate low values for both base and precious metals. Volcanic rocks exposed at the shoreline are pervasively silicified, and massive pyritic lodes are exposed along the beach at the southwest end of the island.

Based on the geochemical anomalies and geologic criteria, we considered tract A1 permissive for the occurrence of porphyry molybdenum, low-fluorine, porphyry copper, volcanic-hosted copper-arsenic-antimony, epithermal gold, and polymetallic vein mineral deposits.

Tract A2 outlines the areal extent of Oligocene plutons and hypabyssal rocks that primarily intrude the nonmarine Tolstoi and Meshik Formations, and the marine Chignik and "Naknek" Formations. The tract is defined by the extent of intrusive activity associated with the Rex prospect (table 3) based on geologic mapping (Detterman, Case, and others, 1987) and aeromagnetic data (Case and others, 1988). Zoned potassic, phyllic, and propylitic alteration surround the prospect. Unpublished geochemical data from Kennecott Corporation indicates that this is a porphyry copper-gold system. They projected the gold grade of this mineralized area to be about 0.7 g gold per ton at 1 percent copper based on a surface rock sampling program; some areas showed copper grades above 0.1 percent (Kennecott Corp., written commun., 1987; published with permission). Based on the geochemical anomalies and geologic criteria, we considered tract A2 permissive for the occurrence of porphyry copper-gold and associated epithermal gold mineral deposits, as well as for polymetallic vein deposits.

Tract A3 is underlain by nonmarine clastic sedimentary rocks of the Tolstoi Formation, which overlie marine clastic rocks of the Chignik and "Naknek" Formations. The tract is defined by the geologic extent of hypabyssal dikes of Oligocene age that intrude tract A3, and by the outlines of drainage basins containing geochemically anomalous samples (map A) associated with tract A3. Sericitic alteration was observed in the upper reaches of Painter Creek (table 3). Geophysical data (Case and others, 1988) suggest that a pluton may exist at depth. Based on the geochemical anomalies and geologic criteria, we considered tract A3 permissive for the occurrence of both epithermal gold and polymetallic vein mineral deposits.

Tract A4 is defined largely on the basis of the inferred extent of a Pliocene pluton (Detterman, Case, and others, 1987) exposed at Cape Igvak. The tract is open offshore and, on the basis of the aeromagnetic map (Case and others, 1988), may include the two magnetic highs to the south. The quartz diorite pluton exposed at Cape Igvak intruded the Jurassic marine sedimentary rocks of the Shelikof and "Naknek" Formations and has propylitically altered the country rocks. The intrusion crosscuts the siltstone member of the Shelikof Formation which contains thin beds of carbonate as well as carbonate cement in the siltstone (Detterman, Case, and others (1987). On the basis of geochemical anomalies and geologic criteria (table 3), we considered tract A4 permissive for the occurrence of porphyry copper, iron skarn, carbonate-hosted gold (Carlin-type), and polymetallic vein mineral deposits.

Two large claim blocks for iron lodes (table 1, nos. 3 and 4) have been staked around the periphery of this Pliocene intrusion. We assume that these are possible iron skarn deposits, although the claims were not examined in the field. The geochemical anomalies are primarily iron, tungsten, and arsenic with much smaller amounts of copper and molybdenum (table 3). The magnetic portion of the heavy-mineral concentrates contains garnet as well as additional scheelite (Church, Frisken, and Wilson, 1989). Although the geochemical signature is more appropriate for the tungsten skarn deposit (Cox, 1986g), the large amounts of magnetite and the large magnetic anomalies associated with this pluton suggest that the area is permissive for the occurrence on iron skarn deposits (Cox, 1986f). Low levels of gold (0.005-0.060 ppm Au) were detected in the magnetite fraction collected from drainage basins south and west of Mount Becharof. Iron might be the primary commodity with some possible tungsten and (or) gold byproduct from these calcic iron skarns (Meinert, 1984). Magnetite lenses are also abundant in the "Naknek" and Shelikof Formations. The highly magnetic character of this pluton may be caused, in part, by the alignment of detrital magnetite within the contact aureole, which surrounds the pluton, with the Earth's magnetic field at the time of the intrusion. Extensive black sand beach placers that occur along the Pacific coast between Dry Bay and Portage Bay, just north of Cape Igvak are evidence of the abundant magnetite in this area.

Tract A5 surrounds the Cape Kubugakli area (table 3) and is confined to the area surrounding the exposed Miocene hypabyssal and plutonic rocks which intrude the marine sediments of the Jurassic Shelikof Formation. Both propylitic and seritic alteration was observed in tract A5. We consider tract A5 permissive for the occurrence of porphyry copper, carbonate-hosted gold (Carlin type), and polymetallic vein mineral deposits.

Quaternary volcanic environment

Mineralization associated with the Quaternary volcanic environment is poorly exposed. Tract A6 outlines two areas of Quaternary volcanic rocks and hypabyssal plugs that intrude Jurassic marine sedimentary rocks in the northern part of the study area. The Kejulik volcanic field (A6a) is summarized in table 3. Field work in the Mount Katmai quadrangle (S.E. Church, 1986, unpub. data), just north of the study area boundary, suggests that mineralization exposed beneath the Kejulik volcano is a porphyry copper-gold deposit. Geochemical anomalies were detected in the drainage basins north and east of Becharof Lake (Bailey and others, 1986) and the geochemical halo extends into the Ugashik-Karluk study area. Only one geochemical anomaly was found on the east side of Ugashik Crater (tract A6b). One lode claim (table 1, no. 5) is located just east of this area. It was not investigated during the field studies. We consider these tracts, A6a and A6b, to be permissive for the occurrence of porphyry copper, polymetallic vein, and epithermal gold mineral deposits.

Tract A7 outlines the outcrop pattern of hypabyssal intrusions that formed the core of an eroded Quaternary volcanic center at Blue Mountain. One small silver anomaly was found in tract A7, and geologic criteria are permissive for the occurrence of either porphyry copper or epithermal gold mineral deposits.

Tract A8, the area around and to the southeast of Mount Kialagvik (table 3), is underlain by Jurassic marine sedimentary rocks intruded by hypabyssal plugs and dikes of late Cenozoic age as well as by dikes and sills of Oligocene age. Finely disseminated sulfides were observed in propylitically altered rocks near Mount Kialagvik. Based on the geochemical anomalies and geologic criteria, we considered tract A8 permissive for the occurrence of porphyry copper, polymetallic vein, and epithermal gold mineral deposits.

Estimate of the number of undiscovered metallic mineral deposits

Estimates of the number of undiscovered porphyry deposits are based on the grade/tonnage curves for producing mines of each type of deposit. Few occurrences have sufficient mineralized ground to be considered possible deposits. Because of the reconnaissance nature of the AMRAP studies, we have made estimates of the number of undiscovered deposits for only the large porphyry systems. Our geologic and geochemical information is too sparce to make estimates of the number of undiscovered deposits where more detailed data are required.

The grade/tonnage curves for the porphyry copper deposit model are given in Richter and others (1975). Based on clusters of geochemical anomalies associated with intrusive centers, observed patterns of alteration, and permissive geologic criteria (table 3), we estimate that there is a 10 percent chance for 2 or more undiscovered porphyry copper deposits in the Ugashik-Karluk study area.

The grade/tonnage curves for the porphyry molybdenum, low-fluorine deposit model are summarized by Menzie and Theodore (1986). Surface sampling of the Mike prospect has outlined an area about 3 km^2 with a molybdenum grade of 0.1 percent and part of the deposit has been drilled to a depth of 30 m. The Mike prospect is considered to be an undiscovered deposit, however, because the drilling program is incomplete and a definitive evaluation of ore reserves has not been made. We estimate a 90 percent chance of one or more porphyry molybdenum, low-fluorine deposits, and a 10 percent chance of 2 or more undiscovered deposits of this type in the Ugashik-Karluk study area.

The grade/tonnage curves for the porphyry copper-gold deposit model are summarized by Singer and Cox (1986). Surface sampling at the Rex prospect indicates that ore grades at the Rex prospect lie on the grade/tonnage curves for this deposit type. We estimate a 90 percent chance of one or more undiscovered porphyry copper-gold deposits and a 10 percent chance of two or more undiscovered deposits of this type within the Ugashik-Karluk study area.

Although not examined in the field, the geologic and geochemical evidence suggest that an iron deposit may be present in tract A4. Two large claim blocks were staked in tract A4; both claim blocks are associated with high magnetic anomalies and magnetite is abundant in the intrusive rocks and in the stream drainages. On the basis of our geochemical data and comparison with the grade/tonnage curves for iron skarns (Mosier and Menzie, 1986), we estimate a 10 percent chance of one or more undiscovered iron skarn deposits in the Ugashik-Karluk study area.

Mineralized rock exposed on David Island (table 3) has the field characteristics of a volcanic-hosted copper-arsenic-antimony deposit (Church, Frisken, and Wilson, 1989). Pyritic lodes are exposed along the beach at the southwest end of the island. However, the geochemical data indicate low values for both base and precious metals. No grade/tonnage curves are available for this type of deposit model because so few deposits of this type have been found, however, the geologic environment for this deposit model type is present in several of the tracts defined above.

Estimates of the number of undiscovered deposits for epithermal gold, for carbonate-hosted gold, and for polymetallic vein mineral deposit models are subject to a large uncertainty due to the reconnaissance nature of this study. These types of deposits have a much smaller geologic and geochemical expression than the larger porphyry mineral deposit systems. Geologic, geophysical, and geochemical evidence for these mineral deposit types occur in several of the tracts outlined on map A (table 4), and the mineral deposit models have been applied to mineralized areas summarized in table 3 as associated mineral deposits. Tracts having favorable geologic and geochemical criteria for the occurrence of this type of mineralization are summarized in table 4.

Evaluation of placer resources in the Quaternary glacial and alluvial environment

The Quaternary glacial-alluvial environment has been investigated for possible placer accumulations of minerals along the tributaries of the major streams. Evidence of the accumulation of gold in the panned concentrates is sparse except for the area around the Rex prospect where Frisken, Church, and Willson (1988) reported several flakes of gold in the panned concentrates from every tributary. The source of placer gold around the Rex prospect is presumed to be the porphyry copper system defined in tract A2. Where these tributaries change gradient abruptly as they enter the larger streams on the Nushagak-Bristol Bay Lowland, conditions are favorable for the accumulation of small placers (Yeend, 1986). The intersection of these tributaries with Volcano Creek on the south, with Wandering Creek on the east, or with the small streams in the headwaters of the Dog Salmon River as well as glacial lake terraces along the north side of the Rex prospect (Detterman, Wilson, and others, 1987) represent areas of possible accumulation for small gold placer deposits.

In our reconnaissance geochemical studies of the Cape Kubugakli area, we detected visible gold in the heavy-mineral concentrates. A sluice box was seen on the bluff above the claims. Gold was also detected in the geochemical studies of tract A8, but the mineralized area seems to be small. Smith (1925) reported gold production from this locality on claims filed by Fred and Jack Mason in 1915 (table 2). Gold was confined to one creek and further exploration by the early prospectors failed to locate additional drainages containing placer gold. Smith (1925) reported a stream width of 2-3 m with an average depth of gravel of about 0.5 m to bedrock at the Mason claims on Cape Kubugakli. Because of the short, steep nature of the drainage and the presence of large boulders in the stream bed, we cannot expect that substantive reserves of placer gold might be produced on Cape Kubugakli or in the surrounding area (Orris and Bliss, 1986). Marine terraces at Cape Kubugakli may also contain some placer gold (Detterman, Wilson, and others, 1987).

We sampled the magnetite-bearing lenses of sandstone, primarily from the "Naknek" Formation, and analyzed them for gold to evaluate them as a source for placer gold. Analyses of 31 samples of this material failed to detect any gold using flame atomic absorption methods (O'Leary and Meier, 1986; detection limit, 0.05 ppm). We conclude that these heavy-mineral-rich lenses within the "Naknek" Formation are not a major source of placer gold in the study area. We observed no gold and did not detect any anomalous gold concentrations in heavy-mineral concentrates collected from drainage basins within the "Naknek" Formation. Placer gold deposits along streams draining areas where the "Naknek" Formation is the major source of heavy minerals (table 2, map nos. 12-17, 19, 20) are considered mineral occurrences. Placer gold in the drainages near the eastern end of Becharof Lake (table 2, map no. 11) was not evaluated. In general, based on the deposit model for placer accumulations in streams (Orris and Bliss, 1986), placer accumulations either for gold or other commodities in the Ugashik-Karluk study area are not expected to become a mineral resource because of the low metal content and small size of the alluvial deposits.

Berryhill (1963, p. 31-33) investigated the beach sands found along the Bering Sea coast south of the mouth of the Cinder River (table 2, map no. 22). He collected 15 auger samples, spaced at 1 mi (1.6 km) intervals, from the black beach sands in this area. Recovery ranged from 0.01 to 0.02 m^3 of material from each site. Panned concentrates prepared from these samples all contained more than 10 percent titaniferous magnetite and pyroxene, and two sites contained flour gold. The TiO_2 content from the Cinder River area black sands ranged from 0.9 to 3.5 kg of TiO_2/m^3. Berryhill (1963) concluded that the beach placers (table 2, map nos. 21-22) along the Bristol Bay coast were not a resource for either TiO_2 or gold. Comparison of the grades of these deposits (0.1-0.2 percent TiO_2/ton) with the grade and tonnage curves for TiO_2 from producing beach placer deposits (ninety percent of the producing deposits have grades in excess of 5 percent TiO_2/ton, Attanasi and DeYoung, 1986) indicates that the Bristol Bay beach placers can only be considered a mineral occurrence. Similar studies of the black sands exposed along the Pacific coast from Dry Bay to Portage Bay and along the shoreline of Wide Bay have not been carried out. However, analysis of magnetite-rich fractions of panned concentrates from the Cape Igvak area indicate a much lower concentration of TiO_2 and a much lower recovery of magnetite in these streams. It appears unlikely that the black sands on the beach between Cape Igvak and Portage Bay is more than a mineral occurrence.

NONMETALLIC MINERAL RESOURCES

Nonmetallic commodities considered include cinder, pumice, and limestone. Other nonmetallic commodities in abundance, but not specifically evaluated as resources include deposits of sand and gravel. Inferred resources for some of the commodities are listed in table 5 and tracts favorable for the occurrence of nonmetallic resources are delineated on map B. The large pumice resource outlined at Aniakchak Volcano (tract B1) is only a part of the deposit which extends into the adjoining Chignik quadrangle (Detterman and others, 1981). Minor amounts of the pumice in the Chignik quadrangle were used for road and airfield construction at Meshik and Port Heiden. No production of pumice can be expected from Yantarni Volcano (tract B2) because of the lack of demand and road access. A considerable amount of cinder mixed with some pumice, volcanic avalanche debris, and fragments of sandstone from the underlying "Naknek" Formation were erupted in 1977 at Ukinrek Maars (tract B3). Ukinrek Maars are located about 2 km south of Becharof Lake and within the Becharof National Wildlife Refuge.

The limestone at Cape Kekurnoi (tract B4) is considered marginally economic. The deposit is at tidewater adjacent to a protected deep-water port, and within easy shipping distance of the population center on Kodiak Island. The Triassic limestone section at Cape Kekurnoi is cut by several dikes and includes a volcanic flow unit, however, many unaltered, thick units of limestone crop out (Detterman and others, 1985). The purity of the limestone was not checked at this locality, however it is probably comparable to the Upper Traissic limestone at Bruin and Iliamna Bays. Analyses of 14 samples collected from the sections at Bruin and Iliamna Bays averaged 46.54 percent CaO, 13.26 percent SiO_2, 1.97 percent Al_2O_3, 1.42 percent Fe_2O_3, and 1.23 percent MgO (Detterman, 1969).

Sand and gravel deposits cover much of the area adjacent to Bristol Bay. Adequate resources are available to meet local demand.

ENERGY RESOURCES

Geothermal Potential

The potential for geothermal energy must be considered in an area that contains six volcanoes of Holocene age. The most recent eruption was at Ukinrek Maars in 1977 (Kienle and others, 1980). Fumarolic activity is present on Mount Chiginagak, the only active hot springs in the study area (map B). The temperature of the hot springs, determined during the course of this study, is 60° C (150° F). The volume of the flow from the hot springs has not been measured, but is estimated to be in the range of 3,000 to 6,000 L/hr. The spring has built a small travertine deposit at the contact between the lava and the alluvium. Miller (1973) reported a possible hot springs near Mount Peulik, and there are springs inside Ugashik crater. When some of these springs were investigated in 1980, all were cold. Smith and Shaw (1975) have calculated a geothermal potential of 129 x 10^{18} calories for the caldera of Aniakchak Volcano located 8 km south of the study area in the Chignik quadrangle. The presence of the hot spring and fumarolic activity at Mount Chiginagak and the eruption at Ukinrek Maars suggest a potentially large geothermal resource within the study area. Each of these sites is indicated on map B.

Oil and Gas Potential

Exploration for oil and gas in the area began in 1902 (Martin, 1904, 1905; Capps, 1923; Smith, 1926). Eighteen exploratory wildcat wells have been drilled. The wells and oil seeps are located on map B; the Standard Oil Pearl Creek locality includes 6 wells. The last exploratory well was completed in 1985. Some of the wells encountered small amounts of oil or gas, but none were considered economic. For consideration of the oil and gas potential, the study area is divided into two tracts, one on the southeast side of the study area and the other on the northwest side, separated by a dashed line. The dashed line marks the western margin of the Bristol Bay Tertiary province (McLean, 1977). This boundary is reflected by a prominent change in the aeromagnetic signature (Case and others, 1988), lithology, structure, and physiographic expression. Tract E1 is coincident with the eastern Bristol Bay basin whereas tract E2 includes the Mesozoic sedimentary rocks exposed in the Alaska-Aleutian Range.

Tract E1 is a Tertiary province consisting mainly of nonmarine volcaniclastic sediments and volcanic rocks. Only a very minor part of these rocks are exposed at the surface. Most of the data was obtained from records from exploratory wildcat wells. Generalized stratigraphic and lithologic data for several wells drilled in the Nushagak-Bristol Bay Lowlands is given by Brockway and others (1975). Geochemical analyses of samples acquired from the General Petroleum Great Basins #1 well were reported by McLean (1977) and were used to evaluate the petroleum potential of tract E1. Briefly, the geochemical analyses show that the rocks are immature and have an average organic content of less than 2 percent carbon. The kerogen present is predominately from woody and herbaceous material. This material could generate thermogenic gas and some oil if it were buried more deeply or exposed to a heat source, such as an igneous intrusion to increase oil maturation. Although such conditions may exist offshore, onshore this province is not expected to have potential for thermogenic oil or gas.

Tract E2 is a Mesozoic sedimentary province that is a part of the Shelikof-Cook Inlet basin. A thick, well-exposed sequence of mainly marine sedimentary rocks are folded into well-defined structures. Two large anticlinal structures, the Ugashik and the Wide Bay-Bear Creek anticlines, are shown on map B. All of the known oil seeps occur and most of the wells are drilled along the crest of these two structures. Oil seeps along the Ugashik anticline are from the lower part of the "Naknek" Formation, whereas the seeps on the Wide Bay-Bear Creek anticline are from the Shelikof Formation. The absence of aeromagnetic anomalies in the Wide Bay-Bear Creek anticline, except near Cape Igvak, was interpreted by Case and others (1988) to indicate a lack of igneous rocks in the core of the anticline. Examination of a series of samples collected from the lower Mesozoic sequence exposed at Puale Bay (L.B. Magoon, written commun., 1980), along with information from the Chignik-Sutwik Island study area to the south (Detterman and others, 1984), are summarized in table 6. In general, these data, as well as the studies of thin sections from the Cities Service Painter Creek well # 1 (McLean, 1977), suggest that the Mesozoic section has poor porosity and permeability. Examination and evaluation of thin sections from the study area also support this conclusion. Diagenetic alteration of the abundant volcanic debris with the formation of zeolites and the weathering of feldspars to clay has greatly restricted reservoir potential. Locally, some of the sandstones in the lower part of the "Naknek" Formation have good porosity and permeability. Bioherms in the Triassic limestone probably have good porosity, but with available data, the locations of these structures in the subsurface are unpredictable. The organic carbon content of the Mesozoic rocks is good and oil has been generated as evidenced by small oil seeps. The lack of commercial oil production from these wells may reflect the poor reservoir characteristics.

Numerous CO_2-rich gas seeps in Becharof Lake adjacent to The Gas Rocks are thought to be of mantle origin. Analysis of gas from The Gas Rocks vent in Becharof Lake shows about 97 percent CO_2 with a carbon isotopic signature of $\delta^{13}C$ of -6.36 per mil, outside the range of carbon isotopic values permissable for organic carbon (Barnes and McCoy, 1979). Other natural gas seeps are reported by Blasko (1976), some of which are associated with oil seeps and are thought to be of thermogenic origin.

Overall, the oil and gas potential for the Mesozoic rocks from tract E2 in the Ugashik-Karluk study area is considered to be low. Oil and gas are present, but the poor reservoir characteristics greatly diminish any potential for economic production.

Coal Resources

Coal and lignite-bearing beds are present in the lower part of the Tolstoi Formation along the southern border of the study area. Three tracts containing coal are shown on map B. Spot observations were made at several localities but the lateral extent is unknown. The quality of the coal was not confirmed by independent analysis, but field observations indicate a range from subbituminous to anthracite. The anthracite occurs near small igneous intrusions. Numerous thin seams, mainly from 2 to 15 cm thick, occur in tracts E3 and E4 (map B). Tract E5 (map B) has several beds 1-2 m thick that were seen on traverses 5 km apart. If the thickness of the coal seams is consistent between these two points, they might have economic potential.

Finally, geologic conditions are permissive for the formation of graphite in the zones of contact metamorphism the coal resource tracts. Segura (1985, p. 10-12) reports that the graphite deposits found in the area of San Jose deMoradillas, Tonichi, and the Alamos mines where formed by contact metamorphism of Triassic(?) sediments containing coal beds. These deposits have large reserves (greater than 1 million tons) of graphite with a grade in excess of 80 percent carbon. Segura (1985) also reports the presence of andelusite in the pelitic rocks in the contact metamorphic zones in Sonora indicating pyroxene hornfels metamorphic grade. In most of the contact metamorphic zones in the Ugashik-Karluk study area, only micas were observed. We have no evidence that the contact metamorphism in tract E5 approached the temperatures of the pyroxene hornfels metamorphic grade. The graphite potential in zones of contact metamorphism in the three coal tracts is low.

SUMMARY AND CONCLUSIONS

On the basis of our geologic mapping, regional geochemical sampling, geophysical studies, and evaluation of mines and prospects as well as studies of newly defined mineralized areas, we have provided an assessment of the metallic and nonmetallic mineral and energy resources of the Bristol Bay, Ugashik, and western Karluk quadrangles. We have outlined eight tracts of ground having defined metallic mineral resources (Map A). The deposit types considered in each tract are summarized in table 4. Most of the deposit model types described are based on mineralized areas investigated in the Ugashik-Karluk study area (tables 1-3) or known to occur on the Alaska Peninsula, although application of the calcic iron skarn and the carbonate-hosted gold deposit models are based on permissive geologic, geochemical, and geophysical evidence.

Estimates of the number of undiscovered deposits, by deposit model type, are made for the large porphyry deposits. We estimate that there is a 10 percent chance for 2 or more porphyry copper deposits in the study area. We estimate that there is a 90 percent chance for one or more undiscovered porphyry molybdenum, low-fluorine deposit, and a 10 percent chance for the discovery of 2 or more such deposits in the southern part of the study area. We estimate that there is a 90 percent chance for the discovery of one or more porphyry-gold deposits and a 10 percent chance for the discovery of 2 or more such deposits in the study area. Finally, we estimate a 10 percent chance for the discovery of one or more iron skarn deposits in the study area. For the other types of deposits considered, the level of our knowledge of the study area was insufficient to make estimates of the numbers of undiscovered deposits. Further detailed mapping at a smaller scale would be required to make these esitmates. However, we consider the geologic, geochemical, and geophysical data permissive for these types of deposits in one or more of the metallic mineral resource tracts outlined on Map A: epithermal gold deposits associated with the porphyry systems, volcanic-hosted copper-arsenic-antimony deposits similar to those observed on David Island, carbonate-hosted gold deposits in the northeastern portion of the study area where plutons intersect the carbonate-rich siltstone member of the Shelikof Formation, and polymetallic vein deposits peripheral to the porphyry systems.

Several placer claims for gold have been filed within the study area and one, located at Cape Kubugakli, has reported production (table 2). The geologic conditions are favorable for the accumulation of small gold placers in the marine terraces on Cape Kubugakli. Gold was seen also in the panned concentrates from stream drainages surrounding the Rex prospect (tract A2). Possible accumulations of placer gold may be present in Volcano Creek, Wandering Creek, or in the tributaries of the headwaters of the Dog Salmon River. We did not find placer gold in drainages underlain by the "Naknek" Formation.

Berryhill (1963) evaluated the TiO_2-rich beach sands along the Bristol Bay coast and conclude that these black sands constituted a mineral occurrence. Likewise, the black sands found north of Cape Igvak to Portage Bay on the eastern coastline are also considered only a mineral occurrence.

Three areas of cinder resources (Map B, tracts B1-B3) are defined. Both the cinder and the sand and gravel resources in the area are adequate for local demand. Limestone located at Cape Kekurnoi is considered marginally economic. Graphite potential associated with the contact metamorphic zone surrounding an intrusive in tract E5 is considered to be low.

The energy resources of the study area include geothermal, coal, and oil and gas. Hot springs located at Mount Chiginagak and fumarolic activity at Ukinrek Maars are strong evidence of geothermal energy at sites having the highest geothermal potential. Smith and Shaw (1975) calculated a large geothermal potential for Aniakchak Volcano located just 8 km south of the study area.

Oil and gas potential was evaluated for two large provinces. Tract E1 is the eastern margin of the Bristol Bay basin. Thermal maturation of the rocks has not been sufficient to produce commercial quantities of oil or gas in the wells drilled. Onshore, this province is not considered prospective for either oil or gas. Tract E2 is a Mesozoic sedimentary province that forms the western margin of the Shelikof-Cook Inlet basin. Numerous oil and gas seeps have prompted wildcat exploratory drilling along the crests of the two major anticlinal structures in the study area. There has been no commercial production of oil or gas from any of these wildcat exploratory wells. Oil and gas are present, as indicated by the presence of the seeps, but the lack of commercial production is a reflection of the poor reservoir characteristics of the rocks. Tract E2 also has a low potential for oil and gas resources.

Coal seams were seen on geologic traverses in the Tolstoi Formation in the southern part of the study area. Grade range from subbituminous to anthracite near the contact with intrusive rocks. Coal potential in tracts E3 and E4 are low because the coal seams are thin. However, in tract E5, several beds of coal 1-2 m thick were seen on traverses 5 km apart. If these beds are continuous, this tract may have commercially producible coal resources.

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MINERAL AND ENERGY RESOURCE ASSESSMENT MAPS OF THE UGASHIK, BRISTOL BAY, AND WESTERN KARLUK QUADRANGLES, ALASKA

By

S. E. Church, R. L. Detterman, and F. H. Wilson

1989

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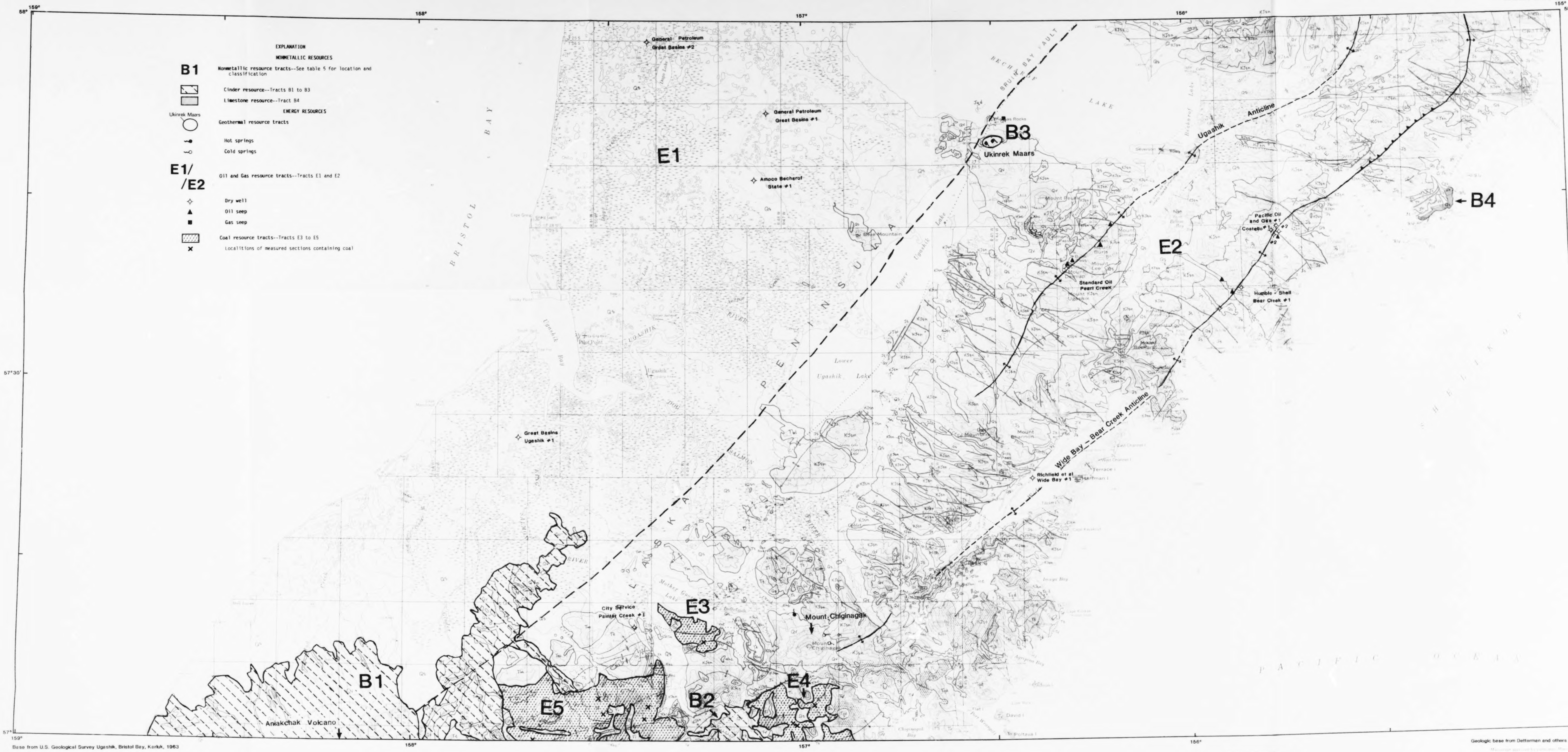
MISCELLANEOUS FIELD STUDIES
MAP MF-1539-I
FOLIO OF UGASHIK, BRISTOL BAY, AND WESTERN KARLUK QUADRANGLES, ALASKA
SHEET 2 OF 2



EXPLANATION

NONMETALLIC RESOURCES

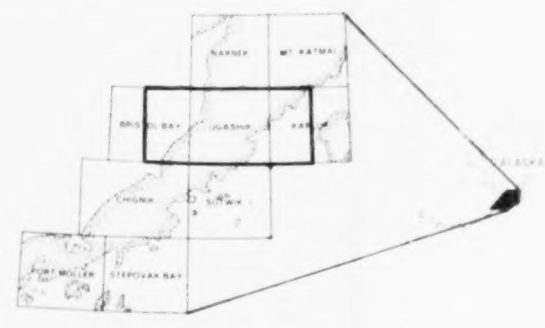
B1	Nonmetallic resource tracts--See table 5 for location and classification
▨	Cinder resource--Tracts B1 to B3
▭	Limestone resource--Tract B4

ENERGY RESOURCES

Ukinrek Maars ○	Geothermal resource tracts
⊸●	Hot springs
⊸○	Cold springs
E1/ /E2	Oil and Gas resource tracts--Tracts E1 and E2
✧	Dry well
▲	Oil seep
■	Gas seep
▩	Coal resource tracts--Tracts E3 to E5
✕	Localitions of measured sections containing coal

Base from U.S. Geological Survey Ugashik, Bristol Bay, Karluk, 1963

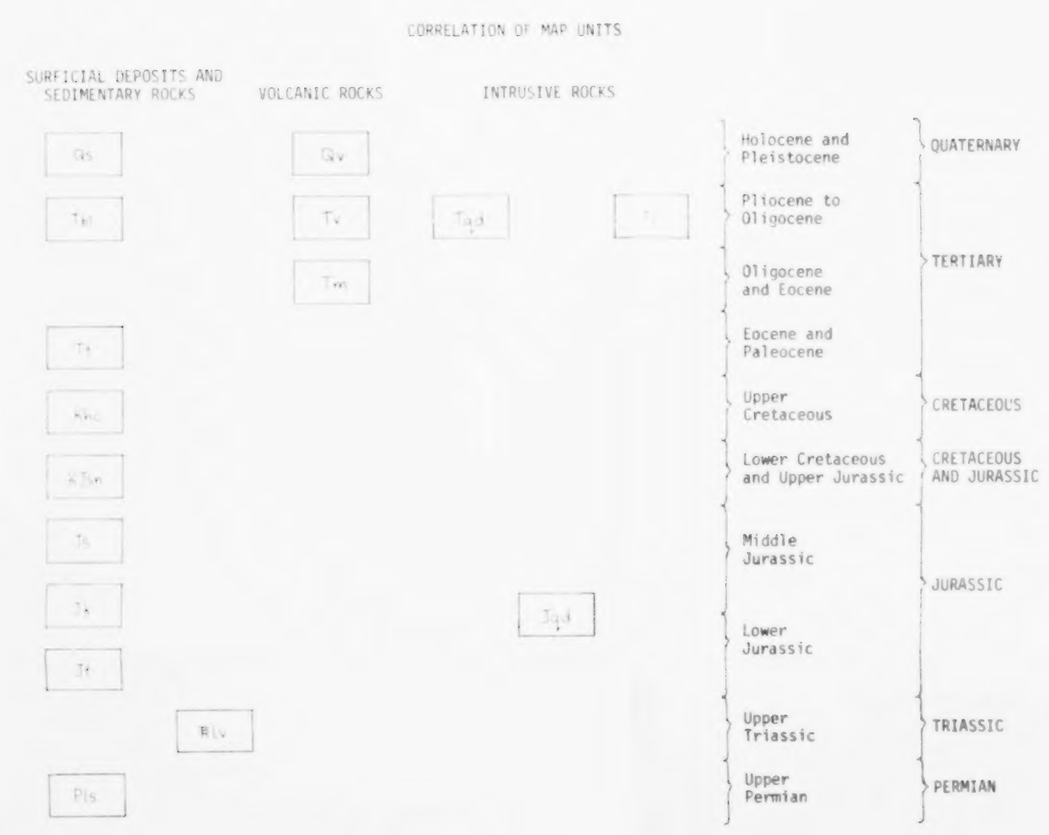
Geologic base from Detterman and others



Map Area

MAP B.-ENERGY AND NONMETALLIC RESOURCES

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS AND SEDIMENTARY ROCKS

Qs	SURFICIAL DEPOSITS (HOLOCENE AND PLEISTOCENE) - Unconsolidated alluvium, alluvial fans, and glacial, marine, lake, swamp, eolian, and landslide deposits; mainly silt, sand, gravel, pumice, and rock fragments
Tbl	BEAR LAKE FORMATION (MIOCENE) - Sandstone, siltstone, shale, minor coal, and conglomerate; nonmarine
Tt	TOLSTOI FORMATION (EOCENE AND PALEOCENE) - Sandstone, conglomerate, siltstone, shale, coal, and tuff; dominantly volcaniclastic and nonmarine
Khc	HOODOO AND CHIGNIK FORMATIONS, UNDIVIDED (UPPER CRETACEOUS) - Hoodoo Formation: dark rhythmically-bedded siltstone and shale, minor thin sandstone; deep-water marine. Chignik Formation: sandstone, conglomerate, siltstone, and shale; mainly shallow marine
KJsn	STANIUKOVICH AND NAKNEK FORMATIONS, UNDIVIDED (LOWER CRETACEOUS AND UPPER JURASSIC) - Staniukovich Formation of Late Jurassic and Early Cretaceous age: thin-bedded feldspathic sandstone, commonly laumontitic; minor siltstone and shale. Naknek Formation of Late Jurassic age: thin-bedded sandstone, siltstone, and dark shale with limestone concretions in upper part. Massive arkosic sandstone and conglomerate in lower part; abundant granitic- and metamorphic-rock clasts in conglomerate. Upper part marine; lower part nonmarine fluvial
Js	SHELIKOF FORMATION (MIDDLE JURASSIC) - Dark siltstone and shale with limestone concretions, sandstone, and conglomerate; nonmarine to near-shore marine, and deep-water turbidite
Jk	KIALAGVIK FORMATION (MIDDLE AND LOWER JURASSIC) - Sandstone, siltstone, mudstone, and shale; mainly shallow water marine
Jt	TALKEETNA FORMATION (LOWER JURASSIC) - Tuffaceous sandstone, siltstone, and limestone; minor bedded tuff
Pls	LIMESTONE (UPPER PERMIAN) - Light-gray massive crystalline limestone

SEDIMENTARY AND VOLCANIC ROCKS

Ꞧlv	LIMESTONE AND VOLCANIC ROCKS (UPPER TRIASSIC) - Light- to dark-gray thin-bedded to massive limestone, limestone conglomerate, and basalt

VOLCANIC ROCKS

Qv	VOLCANIC ROCKS (HOLOCENE AND PLEISTOCENE) - Block and ash flows, debris flows, volcanic mud flows, cinder cones, and andesitic and dacitic lava flows; includes minor hypabyssal rocks
Tv	VOLCANIC ROCKS (PLIOCENE TO OLIGOCENE) - Basalt, andesite, and dacite lava flows, volcanic breccia, and rubble flows; locally includes hypabyssal rocks
Tm	MESHIK FORMATION (OLIGOCENE AND EOCENE) - Basalt flows, volcanic rubble flows, and lahars; locally minor volcanogenic sedimentary rocks

INTRUSIVE ROCKS

Table 1.--Lode mineral occurrences in the Ugashik, Bristol Bay, and western Karluk quadrangles, Alaska

[Mineral abbreviations: py, pyrite; cpy, chalcopyrite; mly, molybdenite; gal, galena; sph, sphalerite; bar, barite; flu, fluorite; stib, stibnite; tet, tetrahedrite; mag, magnetite; --, no data]

Map No.	Geographic Locality	Location	Geologic Description	Minerals Present	Exploration Activity	Deposit Model Type (Cox and Singer, 1986)	Reference
1	Mike prospect	57°04'N 157°13'W	Mineralized rock occurs in a zone of silica flooding around and within a rhyolitic dome overlying a quartz monzonite stock. Sericitic alteration overlaps with the zone of SiO_2 and K_2O enrichment. Pyrite exceeds 5 percent over an area of about 3 km^2; molybdenite occurs as fine veinlets along quartz-filled fractures. A large breccia pipe occurs to the east of this main zone; a small Cu-skarn occurrence is also present.	py, cpy, mly, gal, sph, bar, flu	Three shallow drill holes by Bear Creek Mining Co. in 1977. (Kennecott Corporation, written commun., 1987).	Low-F porphyry molybdenum (deposit model 21b)	Church and others (1989).
2	Rex prospect	57°15'N 157°05'W	Mineralized rock occurs in hornfelsed rocks of the Chignik, Meshik, and Tolstoi Fms. overlying a pluton of Oligocene age. Chalcopyrite is present in both disseminations and stockwork, but molybdenite is present only in stockwork. Galena and sphalerite occur in the prophylitic zone that halos the prospect.	py, cpy, mly, gal, sph, bar, gold	Detailed geochemical exploration by Bear Creek Mining Co. in 1977 (Kennecott Corporation, written commun., 1987).	Porphyry copper-gold (deposit model 20c)	Church and others (1989).
3	Kanatak Lagoon	57°32'N 156°05'W	Lode claims for iron; MacKevett and Holloway (1977) suspect that they may be on magnetite segregations in or around this Pliocene (Wilson and Shew, 1988) granodiorite pluton. Case and others (1988) report very large magnetic anomalies associated with this intrusive. Geochemistry and mineralogy suggests possible Fe-skarn present.	mag	Unknown	Iron skarn(?) (deposit model 18d)	MacKevett and Holloway (1977); U.S. Bureau of Mines (1973).
4	Mount Becharof	57°32'N 156°10'W	---Do---	mag	--Do--	--Do--	---Do---
5	Ugashik River	57°40'N 156°18'W	Lode claim for copper(?) in "Naknek" Fm., possibly a contact zone along the margin of a dike.	--	--Do--	--Do--	---Do---
6	N. Fork Rex Creek	57°39'N 155°51'W	Lode claim for copper(?) in Shelikof Fm., possibly a contact zone along the margin of a dike.	--	--Do--	--Do--	---Do---
7	Sulfur Creek	57°42'N 155°47'W	---Do---	--	--Do--	--Do--	---Do---
8	Puale Bay (Cold Bay)	57°46'N 155°44'W	In 1920, an assay of a lode, consisting of chalcopyrite contained as much as 9.6 g gold, and 250 g silver per ton. This lode, located in rocks of the "Naknek" Fm. at the head of the bay, was reportedly traceable for about 1.5 km. We suspect this prospect is probably in a contact zone along the margin of a sill.	cpy	Location approximate; we were unable to verify this occurrence in the field. Some data in Berg and Cobb (1967).	--	Berg and Cobb (1967); U.S. Bureau of Mines (1973).
9	Cape Kubugalki	57°53'N 155°05'W	Quartz stringers in felsic dikes and Jurassic sedimentary rocks of the Shelikof Fm.	stib, mly, gal, tet, gold, mag	Some placer gold production (see table 2).	Polymetallic vein (deposit model 22c); carbonate-hosted gold (deposit model 26a)	Smith (1925); Cobb (1978).

Table 3.--Geologic, geochemical, and geophysical attributes of several mineralized areas in the Ugashik, Bristol Bay, and wesern Karluk quadrangles, Alaska

[Mineralogical abbreviations: qtz, quartz; py, pyrite; cpy, chalcopyrite; mly, molybdenite; gal, galena; sph, sphalerite; bar, barite; mag, magnetite; hema, hematite; tour, tourmaline; sch, scheelite; flu, fluorite; stib, stibnite; tet, tetrahedrite; cin, cinnabar; --, no data]

Attributes	Tract A1a	Tract A1b				Tract A2	Tract A3	Tract A4	Tract A5	Tract A6a	Tract A8
	Mike prospect	Mt. Chiginagak-Chiginagak Bay	West side of Agripina Bay batholith	Kilokak Creek	David Island Poltava Island Ashiiak Island	Rex prospect	West of Painter Creek and east of Pumice Creek	Cape Igvak-Portage Bay	Cape Kubugakli	Kejulik volcanic rocks	Mt. Kialagvik
Geologic Environment											
Igneous texture and rock type	Qtz eye porphyritic dikes calc-alkaline pluton differentiated to rhyolitic plug	Porphyritic basalt to dacite	Adjacent to porphyritic qtz diorite	Hypabyssal andesite	Porphyritic andesite	Porphyritic qtz diorite	Porphyritic andesite	Medium-grained and porphyritic qtz diorite	Porphyritic andesite	Porphyritic basalt to dacite	Porphyritic andesite dikes
Age of igneous event[1]	Pliocene (2.8-4 Ma)	Late Miocene	Pliocene (2.8-4.2 Ma)	Oligocene (30 Ma)	--	Oligocene and Eocene(31-39 Ma)	Pliocene	Pliocene (2.4-5 Ma)	Miocene (15.6 Ma)	Quaternary	Oligocene (30 Ma)
Country rock[2]	KJsn, Khc, Tt	KJsn, Tt, Tv	KJsn	KJsn, Khc, Tv	Tv	Khc, Tt, Tm	Khc, Tt	Js, KJsn	Js	KJsn	Js, KJsn
Pyritic envelope (color anomaly)	Yes	Yes	Weak in country rock	Yes	No	Yes	Yes	--	--	Yes	Yes
Dike swarms	Yes	Yes	Yes	Yes	--	Yes	Yes	Yes	Yes	Yes	Yes
Tensional fracturing	Yes	--	--	--	No	Yes	--	Yes	--	--	--
Intrusive breccias	Breccia pipe and pebble dikes	No	No	Yes(?)	No	No	No	No	No	No	No
Igneous cupola	Yes	--	--	--	--	Yes	--	Yes	Yes	--	--
Level of erosion	Moderate	Shallow	Shallow to moderate	Shallow	Shallow	Shallow	Shallow	Shallow to moderate	Shallow	Shallow	Shallow

Table 2.--Known placer occurrences in the Ugashik, Bristol Bay, and western Karluk quadrangles, Alaska

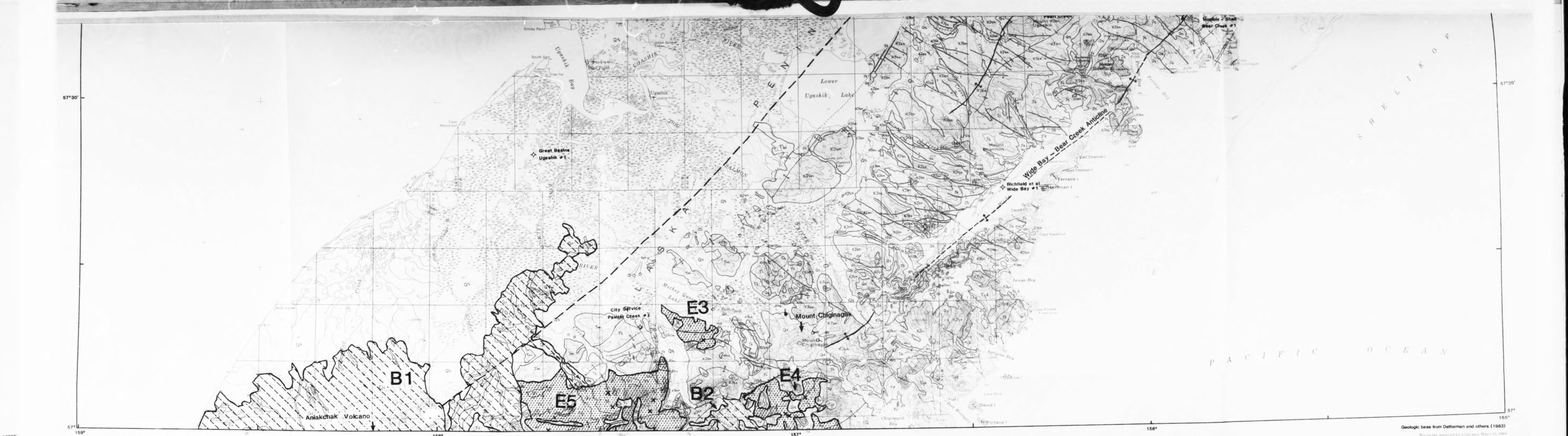
Map No.	Geographic Locality	Location	Commodity	Known Production	Reference
10	Cape Kubugakli	57°53'N 155°05'W	Au	Approx. 160 oz (5 kg)	Smith (1925)
11	Becharof Lake VABM "Marie"	57°55'N 155°57'W	Au	None	U.S. Bureau Mines (1973)
12	Margaret Creek	57°51'N 155°44'W	Au	----Do----	----Do----
13	Trail Creek	57°43'N 155°44'W	Au	----Do----	----Do----
14	Oil Creek	57°42'N 155°44'W	Au	----Do----	----Do----
15	Bear Creek	57°39'N 155°58'W	Au	----Do----	----Do----
16	Salmon Creek	57°38'N 155°59'W	Au	----Do----	----Do----
17	Salmon Creek	57°36'N 155°56'W	Au	----Do----	----Do----
18	Salmon Creek	57°39'N 156°03'W	Mo(?), U(?)	----Do----	----Do----
19	Moore Creek	57°35'N 156°28'W	Au	----Do----	----Do----
20	Pass Creek	57°24'N 156°22'W	Au	----Do----	----Do----
21	Bristol Bay coast Triangulation station "King"	57°53'N 157°38'W	Fe, Ti	----Do----	----Do----
22	Bristol Bay coast south of Cinder River	57°09'N 158°31'W	Fe, Ti, Au	----Do----	Berryhill (1963)

Table 4.--Metallic mineral resource tracts outlined in the Ugashik, Bristol Bay, and western Karluk quadrangles, Alaska

Tract (map A)	Geologic Summary	Summary of Deposit Types (Cox and Singer, (1986)	Mineral Deposit Model (Cox and Singer, (1986)
A1a	Mesozoic marine sedimentary rocks intruded by differentiated Pliocene pluton (Ti)	porphyry Mo, low-F polymetallic vein epithermal gold	21b 22c 25b
A1b	Tertiary nonmarine and volcanic rocks intruded by Oligocene to Pliocene hypabyssal dikes, stocks (Ti), and plutons (Tqd)	porphyry Cu volcanic-hosted Cu-As-Sb polymetallic veins epithermal gold	17 22a 22c 25d
A2	Mesozoic marine and early Tertiary nonmarine sedimentary rocks intruded by Oligocene hypabyssal dikes and plutons (Ti)	porphyry Cu-Au polymetallic veins epithermal gold	20c 22c 25b, 25d
A3	Mesozoic marine and early Tertiary nonmarine sedimentary rocks intruded by Oligocene hypabyssal dikes (Ti)	polymetallic veins epithermal gold	22c 25b, 25d
A4	Mesozoic marine sedimentary rocks intruded by Pliocene pluton (Tqd). Siltstone member of Shelikof Fm. contains some carbonate	porphyry Cu Fe-skarn polymetallic vein carbonate-hosted Au	17 18d 22c 26a
A5	Jurassic marine sedimentary rocks intruded by Miocene hypabyssal pluton (Tqd)	porphyry Cu polymetallic vein carbonate-hosted Au	17 22c 26a
A6	Jurassic marine sedimetary rocks intruded by Quaternary hypabyssal plugs (Qv)	porphyry Cu polymetallic vein epithermal vein	17 22c 25d
A7	Eroded Quaternary hypabyssal plug (Qv)	porphyry Cu epithermal gold	17 25d
A8	Jurassic marine sedimentary rocks intruded by late Cenozoic hypabyssal plutons, dikes, and sills (Qv)	porphyry Cu polymetallic vein epithermal gold	17 22c 25d

Table 5.--Localities and classification of nonmetallic resources in Ugashik, Bristol Bay, and western Karluk quadrangles, Alaska Peninsula

Tract No.	Geographic Area	Rock Type	Volume (10^6 m^3)	Resource Classification (U.S. Bureau of Mines and U.S. Geological Survey, 1980)	Commodity	Land Classification (U.S. Bureau Land Management, 1987)
B1	Aniakchak Volcano	Pyroclastic	1,300	Inferred; marginal	Pumice	Aniakchak National Monument and Preserve Alaska Peninsula National Wildlife Refuge
B2	Yantari Volcano	Pyroclastic	9	Inferred; subeconomic	Pumice	Alaska Peninsula National Wildlife Refuge
B3	Ukinrek Maars	Pyroclastic	5	Inferred; subeconomic	Cinders	Becharof National Wildlife Refuge
B4	Cape Kekurnoi	Limestone	220	Inferred; marginal	Limestone	Katmai National Park and Preserve



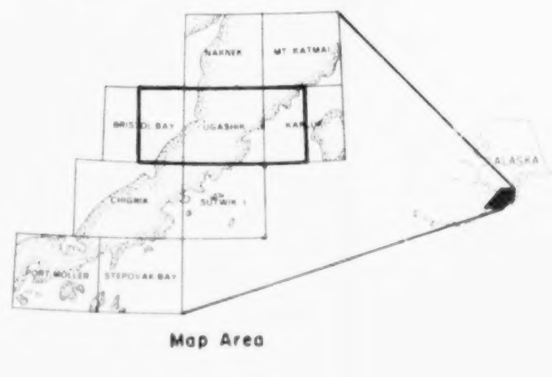
Base from U.S. Geological Survey Ugashik, Bristol Bay, Karluk, 1963

Geologic base from Detterman and others (1983)

Manuscript approved for publication March 21, 1989

SCALE 1:250 000

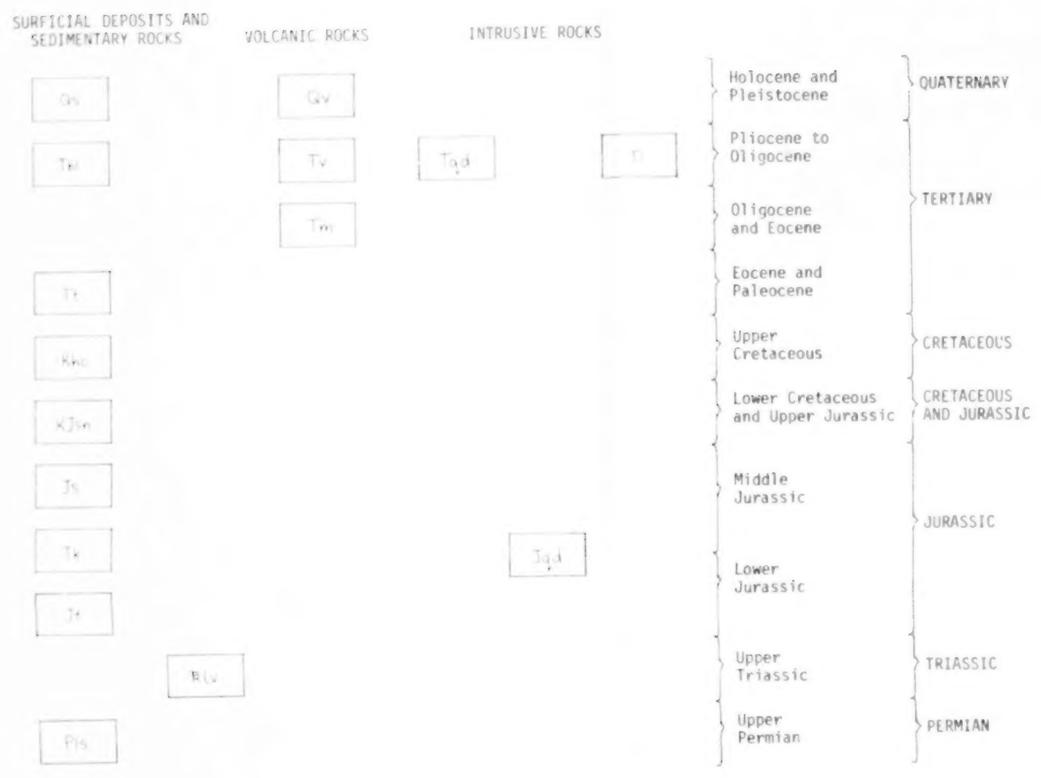
CONTOUR INTERVAL 200 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929



Map Area

MAP B.–ENERGY AND NONMETALLIC RESOURCES

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS AND SEDIMENTARY ROCKS

Qs SURFICIAL DEPOSITS (HOLOCENE AND PLEISTOCENE) - Unconsolidated alluvium, alluvial fans, and glacial, marine, lake, swamp, eolian, and landslide deposits; mainly silt, sand, gravel, pumice, and rock fragments

Tbl BEAR LAKE FORMATION (MIOCENE) - Sandstone, siltstone, shale, minor coal, and conglomerate; nonmarine

Tt TOLSTOI FORMATION (EOCENE AND PALEOCENE) - Sandstone, conglomerate, siltstone, shale, coal, and tuff; dominantly volcaniclastic and nonmarine

Khc HOODOO AND CHIGNIK FORMATIONS, UNDIVIDED (UPPER CRETACEOUS) - Hoodoo Formation: dark rhythmically-bedded siltstone and shale, minor thin sandstone; deep-water marine. Chignik Formation: sandstone, conglomerate, siltstone, and shale; mainly shallow marine

KJsn STANIUKOVICH AND NAKNEK FORMATIONS, UNDIVIDED (LOWER CRETACEOUS AND UPPER JURASSIC) - Staniukovich Formation of Late Jurassic and Early Cretaceous age: thin-bedded feldspathic sandstone, commonly laumontitic; minor siltstone and shale. Naknek Formation of Late Jurassic age: thin-bedded sandstone, siltstone, and dark shale with limestone concretions in upper part. Massive arkosic sandstone and conglomerate in lower part; abundant granitic- and metamorphic-rock clasts in conglomerate. Upper part marine; lower part nonmarine fluvial

Js SHELIKOF FORMATION (MIDDLE JURASSIC) - Dark siltstone and shale with limestone concretions, sandstone, and conglomerate; nonmarine to near-shore marine, and deep-water turbidite

Jk KIALAGVIK FORMATION (MIDDLE AND LOWER JURASSIC) - Sandstone, siltstone, mudstone, and shale; mainly shallow water marine

Jt TALKEETNA FORMATION (LOWER JURASSIC) - Tuffaceous sandstone, siltstone, and limestone; minor bedded tuff

Pls LIMESTONE (UPPER PERMIAN) - Light-gray massive crystalline limestone

SEDIMENTARY AND VOLCANIC ROCKS

Ꞧlv LIMESTONE AND VOLCANIC ROCKS (UPPER TRIASSIC) - Light- to dark-gray thin-bedded to massive limestone, limestone conglomerate, and basalt

VOLCANIC ROCKS

Qv VOLCANIC ROCKS (HOLOCENE AND PLEISTOCENE) - Block and ash flows, debris flows, volcanic mud flows, cinder cones, and andesitic and dacitic lava flows; includes minor hypabyssal rocks

Tv VOLCANIC ROCKS (PLIOCENE TO OLIGOCENE) - Basalt, andesite, and dacite lava flows, volcanic breccia, and rubble flows; locally includes hypabyssal rocks

Tm MESHIK FORMATION (OLIGOCENE AND EOCENE) - Basalt flows, volcanic rubble flows, and lahars; locally minor volcanogenic sedimentary rocks

INTRUSIVE ROCKS

Tqd QUARTZ DIORITE (PLIOCENE TO OLIGOCENE) - Agripina Bay pluton; hornblende-biotite and pyroxene-biotite quartz diorite; medium to coarse grained

Ti INTRUSIVE ROCKS (PLIOCENE TO OLIGOCENE) - Diorite, quartz diorite, hypabyssal andesite and dacite

Jqd QUARTZ DIORITE (MIDDLE AND LOWER JURASSIC) - Medium to coarse grained, hornblende and biotite bearing; part of the Alaska-Aleutian Range batholith

CONTACT--Dotted where concealed

FAULT--Dotted where concealed; queried where probable. U, upthrown side; D, downthrown side. Arrows indicate relative lateral movement

THRUST OR HIGH-ANGLE REVERSE FAULT--Dotted where concealed; sawteeth on upper plate

FOLDS--Showing trace of axial plane; dotted where concealed; queried where probable. Arrow indicates direction of plunge

Anticline

Syncline

LINEAMENT

VOLCANIC CRATER

● VOLCANIC VENT OR CINDER CONE (OTHER THAN WITHIN CRATERS)

░ HORNFELS

▒ ALTERATION--Includes sericitic alteration and silicification

Table 1.--Lode mineral occurrences in the Ugashik, Bristol Bay, and western Karluk quadrangles, Alaska

[Mineral abbreviations: py, pyrite; cpy, chalcopyrite; mly, molybdenite; gal, galena; sph, sphalerite; bar, barite; flu, fluorite; stib, stibnite; tet, tetrahedrite; mag, magnetite; --, no data]

Map No.	Geographic Locality	Location	Geologic Description	Minerals Present	Exploration Activity	Deposit Model Type (Cox and Singer, 1986)	Reference
1	Mike prospect	57°04'N 157°13'W	Mineralized rock occurs in a zone of silica flooding around and within a rhyolitic dome overlying a quartz monzonite stock. Sericitic alteration overlaps with the zone of SiO_2 and K_2O enrichment. Pyrite exceeds 5 percent over an area of about 3 km^2; molybdenite occurs as fine veinlets along quartz-filled fractures. A large breccia pipe occurs to the east of this main zone; a small Cu-skarn occurrence is also present.	py, cpy, mly, gal, sph, bar, flu	Three shallow drill holes by Bear Creek Mining Co. in 1977. (Kennecott Corporation, written commun., 1987).	Low-F porphyry molybdenum (deposit model 21b)	Church and others (1989).
2	Rex prospect	57°15'N 157°05'W	Mineralized rock occurs in hornfelsed rocks of the Chignik, Meshik, and Tolstoi Fms. overlying a pluton of Oligocene age. Chalcopyrite is present in both disseminations and stockwork, but molybdenite is present only in stockwork. Galena and sphalerite occur in the prophylitic zone that halos the prospect.	py, cpy, mly, gal, sph, bar, gold	Detailed geochemical exploration by Bear Creek Mining Co. in 1977 (Kennecott Corporation, written commun., 1987).	Porphyry copper-gold (deposit model 20c)	Church and others (1989).
3	Kanatak Lagoon	57°32'N 156°05'W	Lode claims for iron; MacKevett and Holloway (1977) suspect that they may be on magnetite segregations in or around this Pliocene (Wilson and Shew, 1988) granodiorite pluton. Case and others (1988) report very large magnetic anomalies associated with this intrusive. Geochemistry and mineralogy suggests possible Fe-skarn present.	mag	Unknown	Iron skarn(?) (deposit model 18d)	MacKevett and Holloway (1977); U.S. Bureau of Mines (1973).
4	Mount Becharof	57°32'N 156°10'W	---Do---	mag	--Do--	--Do--	---Do---
5	Ugashik River	57°40'N 156°18'W	Lode claim for copper(?) in "Naknek" Fm., possibly a contact zone along the margin of a dike.	--	--Do--	--Do--	---Do---
6	N. Fork Rex Creek	57°39'N 155°51'W	Lode claim for copper(?) in Shelikof Fm., possibly a contact zone along the margin of a dike.	--	--Do--	--Do--	---Do---
7	Sulfur Creek	57°42'N 155°47'W	---Do---	--	--Do--	--Do--	---Do---
8	Puale Bay (Cold Bay)	57°46'N 155°44'W	In 1920, an assay of a lode, consisting of chalcopyrite contained as much as 9.6 g gold, and 250 g silver per ton. This lode, located in rocks of the "Naknek" Fm. at the head of the bay, was reportedly traceable for about 1.5 km. We suspect this prospect is probably in a contact zone along the margin of a sill.	cpy	Location approximate; we were unable to verify this occurrence in the field. Some data in Berg and Cobb (1967).	--	Berg and Cobb (1967); U.S. Bureau of Mines (1973).
9	Cape Kubugakli	57°53'N 155°05'W	Quartz stringers in felsic dikes and Jurassic sedimentary rocks of the Shelikof Fm.	stib, mly, gal, tet, gold, mag	Some placer gold production (see table 2).	Polymetallic vein (deposit model 22c); carbonate-hosted gold (deposit model 26a)	Smith (1925); Cobb (1978).

Table 2.--Known placer occurrences in the Ugashik, Bristol Bay, and western Karluk quadrangles, Alaska

Map No.	Geographic Locality	Location	Commodity	Known Production	Reference
10	Cape Kubugakli	57°53'N 155°05'W	Au	Approx. 160 oz (5 kg)	Smith (1925)
11	Becharof Lake VABM "Marie"	57°55'N 155°57'W	Au	None	U.S. Bureau Mines (1973)
12	Margaret Creek	57°51'N 155°44'W	Au	----Do----	----Do----
13	Trail Creek	57°43'N 155°44'W	Au	----Do----	----Do----
14	Oil Creek	57°42'N 155°44'W	Au	----Do----	----Do----
15	Bear Creek	57°39'N 155°58'W	Au	----Do----	----Do----
16	Salmon Creek	57°38'N 155°59'W	Au	----Do----	----Do----
17	Salmon Creek	57°36'N 155°56'W	Au	----Do----	----Do----
18	Salmon Creek	57°39'N 156°03'W	Mo(?), U(?)	----Do----	----Do----
19	Moore Creek	57°35'N 156°28'W	Au	----Do----	----Do----
20	Pass Creek	57°24'N 156°22'W	Au	----Do----	----Do----
21	Bristol Bay coast Triangulation station "King"	57°53'N 157°38'W	Fe, Ti	----Do----	----Do----
22	Bristol Bay coast south of Cinder River	57°09'N 158°31'W	Fe, Ti, Au	----Do----	Berryhill (1963)

Table 4.--Metallic mineral resource tracts outlined in the Ugashik, Bristol Bay, and western Karluk quadrangles, Alaska

Tract (map A)	Geologic Summary	Summary of Deposit Types (Cox and Singer, (1986)	Mineral Deposit Model (Cox and Singer, (1986)
A1a	Mesozoic marine sedimentary rocks intruded by differentiated Pliocene pluton (Ti)	porphyry Mo, low-F polymetallic vein epithermal gold	21b 22c 25b
A1b	Tertiary nonmarine and volcanic rocks intruded by Oligocene to Pliocene hypabyssal dikes, stocks (Ti), and plutons (Tqd)	porphyry Cu volcanic-hosted Cu-As-Sb polymetallic veins epithermal gold	17 22a 22c 25d
A2	Mesozoic marine and early Tertiary nonmarine sedimentary rocks intruded by Oligocene hypabyssal dikes and plutons (Ti)	porphyry Cu-Au polymetallic veins epithermal gold	20c 22c 25b, 25d
A3	Mesozoic marine and early Tertiary nonmarine sedimentary rocks intruded by Oligocene hypabyssal dikes (Ti)	polymetallic veins epithermal gold	22c 25b, 25d
A4	Mesozoic marine sedimentary rocks intruded by Pliocene pluton (Tqd). Siltstone member of Shelikof Fm. contains some carbonate	porphyry Cu Fe-skarn polymetallic vein carbonate-hosted Au	17 18d 22c 26a
A5	Jurassic marine sedimentary rocks intruded by Miocene hypabyssal pluton (Tqd)	porphyry Cu polymetallic vein carbonate-hosted Au	17 22c 26a
A6	Jurassic marine sedimetary rocks intruded by Quaternary hypabyssal plugs (Qv)	porphyry Cu polymetallic vein epithermal vein	17 22c 25d
A7	Eroded Quaternary hypabyssal plug (Qv)	porphyry Cu epithermal gold	17 25d
A8	Jurassic marine sedimentary rocks intruded by late Cenozoic hypabyssal plutons, dikes, and sills (Qv)	porphyry Cu polymetallic vein epithermal gold	17 22c 25d

Table 5.--Localities and classification of nonmetallic resources in Ugashik, Bristol Bay, and western Karluk quadrangles, Alaska Peninsula

Tract No.	Geographic Area	Rock Type	Volume (10^6 m^3)	Resource Classification (U.S. Bureau of Mines and U.S. Geological Survey, 1980)	Commodity	Land Classification (U.S. Bureau Land Management, 1987)
B1	Aniakchak Volcano	Pyroclastic	1,300	Inferred; marginal	Pumice	Aniakchak National Monument and Preserve Alaska Peninsula National Wildlife Refuge
B2	Yantarni Volcano	Pyroclastic	9	Inferred; subeconomic	Pumice	Alaska Peninsula National Wildlife Refuge
B3	Ukinrek Maars	Pyroclastic	5	Inferred; subeconomic	Cinders	Becharof National Wildlife Refuge
B4	Cape Kekurnoi	Limestone	220	Inferred; marginal	Limestone	Katmai National Park and Preserve

Table 3.--Geologic, geochemical, and geophysical attributes of several mineralized areas in the Ugashik, Bristol Bay, and wesern Karluk quadrangles, Alaska

[Mineralogical abbreviations: qtz, quartz; py, pyrite; cpy, chalcopyrite; mly, molybdenite; gal, galena; sph, sphalerite; bar, barite; mag, magnetite; hema, hematite; tour, tourmaline; sch, scheelite; flu, fluorite; stib, stibnite; tet, tetrahedrite; cin, cinnabar; --, no data]

	Tract A1a	Tract A1b				Tract A2	Tract A3	Tract A4	Tract A5	Tract A6a	Tract A8
Attributes	Mike prospect	Mt. Chiginagak-Chiginagak Bay	West side of Agripina Bay batholith	Kilokak Creek	David Island Poltava Island Ashiiak Island	Rex prospect	West of Painter Creek and east of Pumice Creek	Cape Igvak-Portage Bay	Cape Kubugakli	Kejulik volcanic rocks	Mt. Kialagvik
Geologic Environment											
Igneous texture and rock type	Qtz eye porphyritic dikes calc-alkaline pluton differentiated to rhyolitic plug	Porphyritic basalt to dacite	Adjacent to porphyritic qtz diorite	Hypabyssal andesite	Porphyritic andesite	Porphyritic qtz diorite	Porphyritic andesite	Medium-grained and porphyritic qtz diorite	Porphyritic andesite	Porphyritic basalt to dacite	Porphyritic andesite dikes
Age of igneous event[1]	Pliocene (2.8-4 Ma)	Late Miocene	Pliocene (2.8-4.2 Ma)	Oligocene (30 Ma)	--	Oligocene and Eocene(31-39 Ma)	Pliocene	Pliocene (2.4-5 Ma)	Miocene (15.6 Ma)	Quaternary	Oligocene (30 Ma)
Country rock[2]	KJsn, Khc, Tt	KJsn, Tt, Tv	KJsn	KJsn, Khc, Tv	Tv	Khc, Tt, Tm	Khc, Tt	Js, KJsn	Js	KJsn	Js, KJsn
Pyritic envelope (color anomaly)	Yes	Yes	Weak in country rock	Yes	No	Yes	Yes	--	--	Yes	Yes
Dike swarms	Yes	Yes	Yes	Yes	--	Yes	Yes	Yes	Yes	Yes	Yes
Tensional fracturing	Yes	--	--	--	No	Yes	--	Yes	--	--	--
Intrusive breccias	Breccia pipe and pebble dikes	No	No	Yes(?)	No	No	No	No	No	No	No
Igneous cupola	Yes	--	--	--	--	Yes	--	Yes	Yes	--	--
Level of erosion	Moderate	Shallow	Shallow to moderate	Shallow	Shallow	Shallow	Shallow	Shallow to moderate	Shallow	Shallow	Shallow
Type of alteration	Sericitic-phyllic surrounding silicified core area	Propylitic	Propylitic and sericitic in country rock	Propylitic and sericitic in country rock	Silicified and altered volcanic rock with quartz veins	Propylitic, phyllic, and potassic alteration	Sericitic	Propylitically altered intrusive, hornfelsed country rock; skarn mineralogical assemblage	Propylitic and sericitic hornsfelsed country rock	--	Propylitic
Observed form of mineralization	Cu-skarn, stockwork, disseminated sulfides, breccias, and vein mineralization	Disseminated	Disseminated in hornfelsed country rock	Disseminated in country rock	Massive pyritic lens	Stockwork and disseminated sulfides	Disseminated sulfides	Disseminated	Disseminated veins	Disseminated	Disseminated
Ore-related minerals observed in the rocks	py, mly, cpy, gal, sph, mag, hema flu	py	py	py, cpy	py, bar rutile	py, cpy, mly gal	py	py, cpy, epidote	py, stib, gal, tet, mly, mag, gold	py	py
Possible mineral deposit models[3]	21b, 22c, 25b	17, 22a, 22c, 25d	22c	17, 22c	22a, 25d	20c, 22c, 25b, 25d	22c, 25b, 25d	17, 18d, 22c, 26a	17, 22c, 26a	22c, 25b	17, 22c, 25b
Geochemical Expression											
Anomalous elemental concentrations in stream sediments[4]	Cu, Mo, Ag, Pb, Zn, B	Mo, Ag, Pb, Zn	Mo, Ag, Pb, Zn, B	Cu, Mo, Pb, Zn, B	--	Cu, Mo, Ag, Pb, Zn	Cu, Pb, Zn, B	Mo, Ag, Pb, Zn, B	Mo	--	Cu, Mo, Pb, Zn, B
Anomalous elemental concentrations in panned concentrates[5]	Cu, Mo, W, Ag, Pb, Zn, As, Cd, Ba, B, Bi, Au, Sn	Cu, Mo, W, Pb, Ag, Zn, B, As, Cd, Ba	Cu, Mo, W, Ag, Pb, Zn, B, As, Cd, Ba	Cu, Mo, Pb, As, Ag, Au, Ba	--	Cu, Mo, Pb, Ag, As, W, Au, Bi	Cu, Mo, Ag, Pb, Zn, B, As, Bi, Cd, Ba	Cu, Pb, Ag, Zn, B, As, W, Cd, Sn, Bi	Cu, B, Au, Ag, W	Cu, Mo, Ag, Sn, Cd	Cu, Pb, Zn, B, As, Bi, Ba
Mineralogy of the nonmagnetic heavy-mineral conentrates[6]	py, cpy, mly, sph, gal, tour, bar, cin, rutile	py, cpy, mly, tour, sph, bar	py, cpy, gal, cin, bar, tour, gold	py, cpy, tour, cin, bar, gold	--	py, cpy, sch, gold, tour	py, cpy, sph, cin, tour, bar	py, cpy, gal, sph, sch, tour, rutile, bar	py, cpy, tour, sch, gold	py, mly, gold, bar	py, bar
Anomalous elemental concentrations in rocks[7]	Cu, Mo, Pb, Zn, Ba, Au, Ag	Cu, Pb, Zn	Cu, Mo, Ba, Pb, Zn, Au	Cu, Pb, Ba, Au, Zn	Cu, Mo, Pb, Ag, As, Bi	Cu, Mo, Pb, Zn, Ag, Ba	Cu, Pb, Zn, Ba	Cu, Mo, Pb, Zn Ba, As, Ag	Cu, Mo, Pb, Zn, Au, Ag	--	Cu, Mo, Pb, Zn, Ba
Geophysical Expression											
Magnetic signature	Magnetic high to east of altered area underlain by pluton (area 17)[8].	Magnetic anomalies suggest buried plutons at depth; small hypabyssal plutons exposed (areas 19-22)[8].	Magnetic anomalies variable; band of magnetic anomalies along contact of intrusive (area 23)[8].	Magnetic high over Cape Kiloikak caused by intrusive; small lows may indicate hydrothermal alteration (area 23)[8].	Strong magnetic low occurs over altered volcanic rocks of David Island (area 24)[8].	Magnetic highs over pluton; magnetic low may be due to hydrothermal alteration (area 14)[8].	Magnetic high implies pluton at depth; magnetic low coincides with the altered area (area 16)[8].	Prominent magnetic high of more than 1000 gammas caused by quartz diorite pluton north of Cape Igvak (area 29)[8].	Prominent magnetic low of 200 gammas occurs over the Cape and extends offshore to the east (area 32)[8].	Small magnetic anomalies probably associated with Kejulik volcanic flows (area 13)[8].	Highly variable magnetic signature over anomalous areas caused by volcanic rocks from Mt. Kialagvik (area 25)[8].

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[1] Wilson and Shaw (1988)

[2] Detterman and others (1983)

[3] Cox and Singer (1986)

[4] Church and others (1988)

[5] Frisken, Church, Detra, and Willson (1988)

[6] Frisken, Church, and Willson (1988)

[7] Wilson and O'Leary (1986; 1987)

[8] Areas shown in description of magnetic signatures from Case and others (1988).

Table 6.--Data for assessment potential of Mesozoic rocks Ugashik and western Karluk quadrangles, Alaska

Stratigraphic unit	Lithology and Depositional Environment	Thickness, in meters	Porosity (%) Permeability (mD)	Average Organic Carbon (Wt.%)	Maturation Index	Remarks
Hoodoo Formation	Siltstone and shale; minor sandstone; marine.	<150	No data	3.6 from adjoining area (Detterman and others, 1984)	Mature.	Present only along Shelikof Strait; not thought to be prospective onshore; may be prospective under Shelikof Strait.
Chignik Formation	Thin-bedded sandstone, siltstone, mudstone and shale, limestone concretions; marine.	50-100	1.9-8% 0.26-2.06mD	13.2 from adjoining area (Detterman and others, 1984)	Mature.	Present locally; sandstones dirty and diagenetically altered; porosity and permeability probably less than in adjoining area; not considered prospective.
"Naknek" Formation	Upper part thin-bedded shelf sandstone; middle part siltstone; lower part sandstone and conglomerate, marine and nonmarine.	750-2,300	1.5-5.4% 0.08-0.39mD in lower part only	No data	Mature.	Numerous thick sandstones and conglomerate are prospective, but zeolite formation and alteration of feldspar to clay may have closed most pore space.
Shelikof Formation	Volcaniclastic sandstone, conglomerate, and siltstone; marine neritic to deep water.	1,000-1,500	1.3-11.9% Average 5.26% 0.01-1.17mD Average 0.19mD	3.3	Mature to supramature.	Thick sandstone and conglomerate locally with good porosity and permeability, but compaction and diagenetic alteration has greatly reduced both porosity and permeability.
Kialagvik Formation	Fine-grained sandstone, siltstone, shale, and minor amounts of conglomerate; marine.	700-900	No data	1.3	Mature to supramature.	High argillaceous content of sandstone and diagenetic alteration of minerals greatly reduced both porosity and permeability.
Talkeetna Formation	Calcareous and tuffaceous sandstone, siltstone, tuff, and minor amounts of limestone; marine.	200-300	3.4-6.1% 0.02-0.07mD	No data	Mature to supramature.	Diagenetic alteration of tuff has greatly reduced permeability; not considered prospective.
Triassic Limestones	Thin-bedded to massive limestone, shale, conglomerate, and minor amounts of volcanic rocks; inner shelf marine.	700-800	No data	0.91	Mature to supramature.	Fine-grained silicified, and partly recrystallized limestone not considered prospective. Local reef structures may have good porosity.

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CHURCH AND OTHERS—RESOURCE ASSESSMENT MAPS, UGASHIK, BRISTOL BAY, W. KARLUK QUADS., ALASKA 1:250,000 MAP MF-1539-I

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